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Manned Undersea Science and Technology Fiscal Year 1976 Report

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COVER: NOAA-sponsored international fisheries project completed during September and November 1975, 8½ miles off Rockport, Mass., is shown in artist's conception. Working from the 100-ton, two-room West German Underwater Laboratory *HELGOLAND,* Department of Commerce and university scientists seek to learn how the environment affects herring spawning and to improve sonic techniques for estimating populations of major commercial fish. Scientist-divers work near the *HELGOLAND* while others observe from small submersible at upper right.

Manned Undersea Science and Technology Fiscal Year 1976 Report

Rockville, Md.
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U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Robert M. White, Administrator

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INTRODUCTION AND SUMMARY

This fifth annual report of the National Oceanic and Atmospheric Administration (NOAA) Manned Undersea Science and Technology (MUS&T) Program presents a general review of the Program's development and management, a summary of significant accomplishments during its first 5 years, and a detailed description of new and ongoing activities in the period July 1975 to September 1976. A bibliography documenting MUS&T-supported activities during the first 5 years of operations is also provided.

The purpose of the Program is primarily to foster those manned underwater scientific investigations that meet the needs and requirements of NOAA and to encourage studies and activities that increase the safety and versatility of manned undersea operations. The program also provides liaison, advice, and support to Federal, State, and academic bodies performing manned undersea work.

During the time period of this report (fiscal year 1976 plus the 1976 transitional quarter year) considerable emphasis was directed to interagency activities involving diver safety, underwater physics research, and the use of submersibles for underwater environmental studies. In response to a request initiated by Congress, MUS&T made a special study of requirements for improving manned underwater technology capabilities to support U.S. underwater scientific and engineering endeavors and missions.

Considerable attention was given to the role the MUS&T Program plays in national civil manned undersea activities during this report period. An assessment of the MUS&T Program was made by the Panel on Undersea Facilities of the Marine Board, Assembly of Engineering, National Research Council. And, in response to Congressional interest in manned undersea research, science, and technology, an audit program was begun by the General Accounting Office in the summer of 1976 to determine past and present problems, achievements to date, and the potential of manned underwater activity.

The MUS&T Office also served as the management focus for NOAA in a 3-year exploratory cost- and use-sharing arrangement for the deep-sea research submersible *Alvin*. This arrangement began in calendar 1975 in partnership with the National Science Foundation and the U.S. Navy. Growth of NOAA's diving program and MUS&T's increasing role in U.S. civil diving safety activities are reviewed.

International cooperative man-in-the-sea programs continued. A major research program in support of the fisheries management research effort of NOAA's National Marine Fisheries Service's Northeast Fisheries Center was concluded off the Massachusetts coast near Rockport. This effort involved the cooperative use of the West German underwater laboratory *HELGOLAND*, brought to the United States in 1975 on a fisheries factory ship operated by the Polish Fisheries Central Board. In the summer of 1976, U.S. scientists and technologists also participated in the Lubeck *HELGOLAND* underwater laboratory operation, which is managed by the West German firm, Gesellschaft fur Kernenergieverwertung in Schiffbau und Schiffahrt (GKSS), Geesthacht, Federal Republic of Germany (FRG).

Activities of FY 1976 are described under the following categories: requirements and systems analyses; operations effectiveness and safety; technology studies, development, and transfer; marine science applications; interagency activities; and international activities.

BACKGROUND

The MUS&T Program was created to fulfill part of NOAA's responsibility for significantly increasing our knowledge of the ocean's resources and processes. Impetus for its formation came from recommendations by the National Marine Council, various advisory panels, and the Commission on Marine Science, Engineering, and Resources.

Although initial funds for the Program were not available until August 1971, staffing and planning began in December 1970. The MUS&T Program was assigned to the NOAA Associate Administrator for Science and Technology until September 1971, when it was transferred to the Associate Administrator for Marine Resources.

Funds appropriated to the MUS&T Program have been budgeted into five broad functional categories—operational effectiveness, safety, and technical coordination; fisheries research support; environmental research support; submersible *Alvin* support; and other scientific research. (See discussion of funding under Five-Year Summary of MUS&T Activities.) Manned platforms have been leased through contracts and grants to universities and to operators of the platforms, based on competitive and sole-source procurement. Maximum cost effectiveness has been sought through the cooperative involvement and support of other agencies engaged in underwater research. Scientific and technical programs have been selected from more than 200 unsolicited proposals. These were reviewed by members of the MUS&T staff and outside reviewers. Selection of programs is based on national goals and needs, and the priorities recommended or suggested by appropriate review panels or individuals from the private sector and from government.

Scientific operations have been conducted in the Atlantic and Pacific Oceans, the Bering Sea, the Arctic, and in the Baltic Sea. The missions support NOAA's MUS&T Program objectives in marine science, particularly the evaluation and development of our marine resources. Knowledge gained from these projects is also used to plan longer range and more extensive marine endeavors and to solve day-by-day problems arising from competing interests in coastal and inland waters and the deep ocean.

OBJECTIVES

The basic objectives of the Manned Undersea Science and Technology (MUS&T) Program are to:

- Provide manned underwater and operational support to NOAA and other agencies investigating marine resources and environmental problems for which subsurface observations and collection of data by man are required.
- Develop, support, and manage a NOAA diving program to assure safe diving and more efficient operations for prolonged manned missions in coastal waters and on the continental shelf.
- Synthesize data from MUS&T-supported investigations and disseminate to user community to improve understanding of the nature and availability of marine resources.
- Foster and coordinate manned undersea science projects with Federal and State agencies, industry, institutions, and universities.
- Develop scientific and technical criteria for the design of civilian undersea facilities and platforms, through experience gained by using available habitats and submersibles.
- Encourage and coordinate the transfer of undersea technology, including advances in diver technology and all civilian, military, and foreign undersea scientific and technological developments.

These objectives are being pursued by a small staff of technical personnel that is acquainted with Federal, industrial, and academic underwater programs and interests and whose standing in the marine science and technology community is well recognized. The staff's programing endeavors are guided by the advice of other NOAA components and by the suggestions and recommendations of such bodies as the National Academy of Science and National Academy of Engineering (NAS/NAE), the Interagency Committee on Marine Science and Engineering (ICMSE), and representatives from industrial and academic organizations.

FIVE-YEAR SUMMARY OF MUS&T ACTIVITIES

The Manned Undersea Science and Technology (MUS&T) Office in NOAA has supported civilian operational capabilities for man to work under the sea in support of programs that aim to achieve a better understanding, assessment, and use of the marine environment and its resources.

MUS&T has supported NOAA investigations involving marine resources and environmental problems for which manned, subsurface observations and data collection are required. In addition, MUS&T has continued to assess the Federal civilian agency needs for submersibles and habitats, and to coordinate the use of available commercial and Navy assets by the civilian Federal agencies as recommended by the Interagency Committee on Marine Science and Engineering (ICMSE). MUS&T has coordinated the use of available undersea shallow-water platforms for scientific projects jointly sponsored by NOAA and other Federal agencies including Army Corps of Engineers, Energy Research and Development Administration, Environmental Protection Agency, National Aeronautics and Space Administration, and U.S. Geological Survey. Together with the U.S. Navy and the National Science Foundation, NOAA has funded the operation of the deep research submersible *Alvin,* operated by the Woods Hole Oceanographic Institution, as part of the University National Oceanographic Laboratory System.

Shortly after initial program funding in late 1971, MUS&T began to sponsor NOAA diving activities. These have included over 25 different projects involving the use of 9 different U.S. research submersibles and 6 different ocean-floor laboratories or habitats and over 125 missions involving almost 500 diving scientists (fig. 1).

The apportionment of the MUS&T funding for the first 5 years is shown in figure 2 for broad functional areas: operational effectiveness, safety, and technical coordination (including requirements and systems analyses); fisheries research support; environmental research support (including ocean dumping and the Bahama Banks Research Program); and *Alvin* support provided to the Woods Hole Oceanographic Institution. Of the total $5,800,000 available during this period, two-thirds has been spent out-of-house. This is shown in figure 3, which presents the funding in four categories; submersible leases, habitat leases, and research project support (all three outside MUS&T), and salaries, travel, supplies, and equipment (MUS&T expenses).

FISCAL YEAR 1972—SEPTEMBER 1971 THROUGH JUNE 1972

Formulated diving technology and physiology program that led to systematic investigations and new data in saturated and other diving activities in succeeding years.

Used eight submersibles and two habitats as follows:

- Northeast Coast Fisheries Investigations: Phase 1, Perry *PC-8;* Phase 2, Perry *Deep Diver.*
- New York Bight Program: Phase 1, Perry *PC-8;* Phase 2, Westinghouse *Deepstar 2000.*
- Hudson Canyon Investigations: *Alvin.*
- Bahama Banks Research Program—Submersible Investigation: *PC-8* and *Alvin.*
- Bahama Banks Research Program—Habitat Program: Perry *HYDROLAB* for five missions.
- Florida Aquanaut Research Expedition (FLARE): University of New Hampshire habitat *EDALHAB* for 12 missions.
- Straits of Florida Sediment Studies: *Alvin.*
- Texas Flower Garden Reef Survey: *Nekton Gamma.*
- Glovers Reef Carbonate Platform Studies: *Nekton Beta.*
- Southern California Borderlands Investigations: Lockheed *Deep Quest.*
- Pacific Walrus Study: Perry *PC-8.*

Formulated plans for international programs, including Project FAMOUS (French-American Mid-Oceanic Undersea Study) in conjunction with the National Science Foundation and the U.S. Navy.

FISCAL YEAR 1973—JULY 1972 THROUGH JUNE 1973

Placed increased emphasis on coastal zone resource and ecological matters.

Used underwater laboratory habitat Perry *HYDROLAB* almost continuously (27 missions) near Freeport, Bahamas, in the Bahama Banks Research Program. New data were collected on reef ecology

Figure 1.—MUS&T science projects, FY 1972-76.

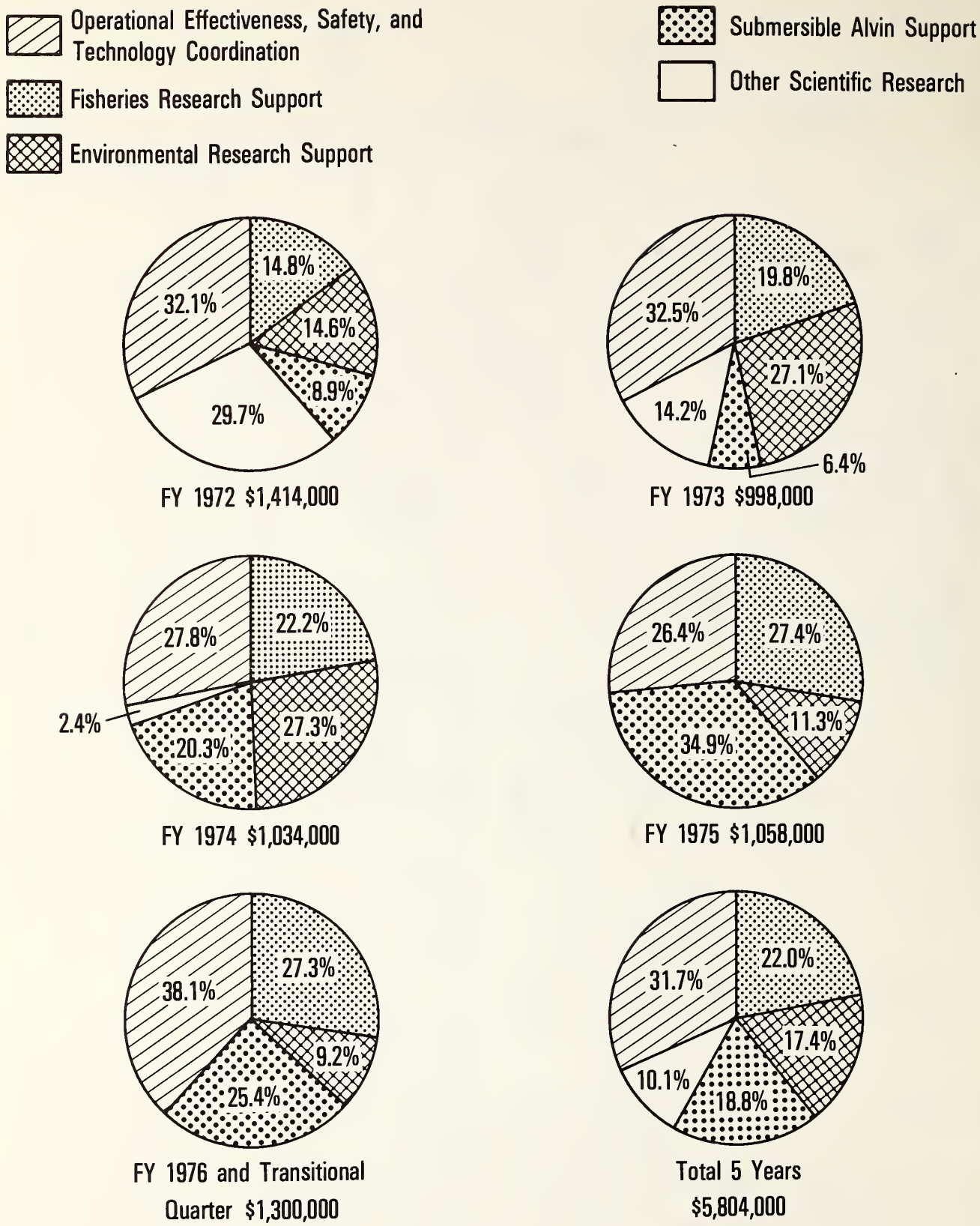


Figure 2.—MUS&T funding by broad functional areas, FY 1972-76.

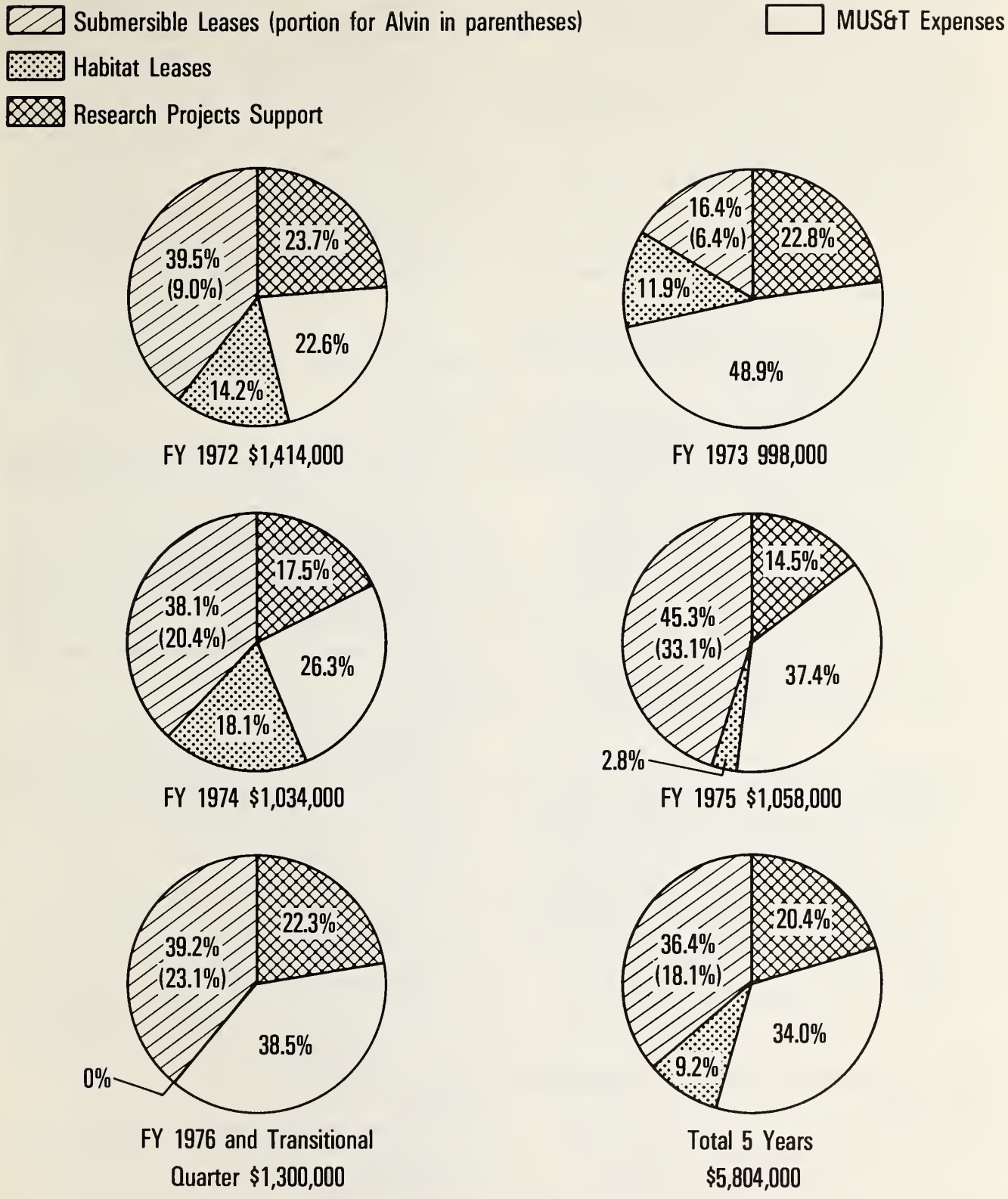


Figure 3.—MUS&T funding spent out-of-house and in-house, FY 1972-76.

and structure and how such pollutants as crude oil affect the marine ecology and environment.

Used the *LA CHALUPA* of the Puerto Rico International Underwater Laboratory (PRINUL) for six MUS&T-sponsored missions off Puerto Rico.

Studies and workshops produced:

- o A National Academy of Sciences (NAS)/National Academy of Engineering (NAE) workshop assessing civil manned undersea activities.
- o A NOAA-Coast Guard study of fatal accidents of civilian divers.
- o A study of the requirements of the U.S. marine science community with respect to future underwater platforms, in particular ocean-floor laboratories.
- o A study of the status of civil manned underwater platforms and their planned use by Federal agencies; for the Interagency Committee on Marine Science and Engineering.
- o A study under a NOAA-Navy diving physiology and biomedical research program to extend the useful range of excursions of saturated divers during science missions.
- o Beginning of a diver population study.

Submersible and other diver operations included:

- o Use of submersible *Alvin* to investigate the Hudson Canyon.
- o Use of submersible *Nekton Gamma* for fisheries research study of lobsters.
- o Use of submersible *Nekton Beta* for British Honduras Carbonate Platform investigation.
- o Use of surface diving to study herring spawning.

International and interagency activities included:

- o Intensified planning for a United States/French Mid-Atlantic Ridge survey program using the United States submersible *Alvin* and the French submersibles *Archimede* and *SP3000* in mid-1974, and the beginning of a French-American Man-in-the-Sea program. Discussed the exchange of technology and science information and possible joint underwater ventures with the Federal Republic of Germany and Japan.
- o Studied and analyzed interagency mission requirements extensively for the first time.*

FISCAL YEAR 1974—JULY 1973 THROUGH JUNE 1974

NOAA Diving Program activities follow:

- o The *NOAA Diving Manual* was begun.
- o NOAA diving regulations were revised.
- o A NOAA diving medical review board was established.
- o Federal Aviation Administration (FAA) agreed to cooperate with NOAA/MUS&T for diver medical examinations.
- o Comprehensive studies were continued on the diving population, underwater fatality statistics, and bone necrosis.
- o NOAA sponsored use of the Perry *LA CHALUPA* habitat (operated by the Puerto Rico International Underwater Laboratory Program) to field test vertical excursion diving procedures developed in cooperation with the U.S. Navy. From a saturated depth of 100 ft, a total of 20 man-excursions were made to a depth of 250 ft, demonstrating the feasibility of this method for extending the operational effectiveness and range of operation of saturation diving.

Technology activities

- o Supported U.S. Navy diver technology programs in studies and evaluations of blood bubble detectors, portable inflatable recompression chambers, and digital decompression computers.
- o Participated in an interagency program of instrument development and deployment for nuclear activation studies of the ocean bottom—the result of feasibility studies begun in FY 1973—and developed plans for a submersible mission in Long Island Sound to test several activitation techniques.

Marine science applications

- o A herring egg survey was made off the U.S. northeast coast near Jeffreys Ledge. Important new information was obtained on the distribution of eggs and ecology of herring.
- o A study of abandoned lobster (ghost) pots was made near Woods Hole, Mass.
- o Improved diver surveys of pollution and dumpsites were made from surface vessels.
- o The Bahama Banks Research Program, using the Perry *HYDROLAB,* was continued. Twenty-five missions were performed on diver training, coral reef ecology and metabolism, shallow-water oceanography, instrument calibration, cosmic-ray muon stopping functions, fish behavior, oil pollution, and light penetration.

Interagency and international activities

- o The first substantial report on Federal agency use of manned underwater activities was issued by the Interagency Committee on Marine Science and Engineering.
- o German scientists worked from the Perry *HYDROLAB* off Grand Bahamas Island, and U.S. divers visited the German underwater

* Published as Manned Undersea Activities of the Federal Agencies and Utilization of Submersible and Habitats December 1972. U.S. Government Printing Office.

laboratory *HELGOLAND* off the north German coast at the island of Helgoland.

- The French-American Project FAMOUS reached final planning stages for a summer mission in 1974. A seismological data survey was made of the FAMOUS site in summer and autumn of 1973. Several research vessels and submersibles did preliminary surveys on the topographic and heat-flow characteristics of the ocean bottom.
- A joint American and Japanese diving program was begun in July 1973 at Yokosuka, Japan. Divers from the Japan Marine Science and Technology Center (JAMSTEC) and the University of Hawaii learned important new information on body heat and fluid balance in a hyperbaric, helium-oxygen environment.

FISCAL YEAR 1975—JULY 1974 THROUGH JUNE 1975

NOAA Diving Program

- Progress was made in developing diving safety and technology.
- As a result of NOAA's sponsorship of diving research, important diving data were acquired and new diving tables for excursions from underwater laboratories and lockout submersibles were produced.
- Made progress in development of a portable inflatable recompression chamber and, with NOAA fiscal support began development of a wrist-worn decompression computer under the auspices of the Naval Undersea Center's Hawaii Laboratory.
- The *NOAA Diving Manual* (U.S. Government Printing Office Stock Number 003-017-00283) was published. The Manual, which is designed especially for NOAA working and scientific divers, principally addressees "shallow" water diving (surface to 300 ft) as this is the deepest range in which NOAA divers primarily operate. The *NOAA Diving Manual* contains the basic information and applied diving technology needed to carry out NOAA's scientific investigations and the tasks required of NOAA divers. NOAA also developed standards, operational plans, and safety requirements for using research submersibles and established standards for use of NOAA recompression facilities, including training and certifying of chamber operators. In addition, NOAA and the U.S. Coast Guard developed procedures for compiling information on fatal scuba diving accidents (primarily recreational) through a grant to the University of Rhode Island.

Technology

- A study of nuclear (X-ray and neutron) activation in Long Island Sound was made in July 1974. The AEC (now ERDA), NASA, and U.S. Geological Survey participated. The submersible *Beaver Mark IV* was used. New data on sea-bottom heavy metal pollutants were obtained.

Marine science applications

- Studies of herring egg beds and megabenthic fisheries were continued off the U.S. northeast coast. Beginning in December 1971, NOAA supported the use of the Perry *HYDROLAB* in some 80 missions during the Bahama Banks Research Program near Freeport, Grand Bahama Island. A series of deep excursion dives completed this activity in April 1975. During the year, the 21 missions performed at *HYDROLAB* included studies in physiology, biology, instrument test and evaluation, and cosmic rays. The last mission, Project SCORE, used saturation diving, deep air excursions, and submersible lockout techniques for deep reef studies of fish, corals, algae, and geology of the reef environment. It was done in cooperation with the Smithsonian Institution and the Harbor Branch Foundation using the *Johnson Sea-Link* lockout research submersible and the Perry *HYDROLAB*. Since the first saturation dive using the Perry *HYDROLAB* (May 1971), through April 1975, there have been 314 individual saturation dives made by 212 different individuals, 22 of them by women—accounting for a total of 1,682 person-days, or over 4-1/2 person-years spent in saturation.
- Experiments in the ecology of marine fauna and dumpsite surveys continued off the U.S. northeast coast using the submersible *Alvin*.

International activities

- Completed Project FAMOUS (French-American Mid-Oceanic Undersea Study), using the United States submersible *Alvin* and two French submersibles to obtain data on geologic processes along midocean ridges in the mid-Atlantic.
- Completed a joint United States and West German 3-week undersea research project (science diving mission) in the Baltic Sea during August 1974, during which data on the ecology and biology of these colder, darker waters were gathered.
- Began planning a major underwater research mission using the West German underwater laboratory *HELGOLAND* about 9 miles off Rockport, Mass. The project was named First International Saturation Study of Herring and Hydroacoustics (FISSHH).

Interagency activities

- The second Interagency Committee on Marine Science and Engineering report was prepared.

FISCAL YEAR 1976 AND FISCAL TRANSITIONAL QUARTER—JULY 1975 THROUGH SEPTEMBER 1976

Systems engineering

- o The concept of an "Ocean Lab" was refined. A preliminary system design and cost analysis contract was prepared for award to industry in October 1976.

Requirements & Systems Analysis

- o The NOAA Diving Manual was widely distributed and became an accepted document by various diver organizations.
- o The Marine Board of the National Research Council prepared a milestone report on, and analysis of, MUS&T roles and functions and a new view of the needs and problems of underwater activities.
- o GAO also began an in-depth analysis and audit of U.S. civil underwater projects and aspirations and MUS&T's role.

Technology and applied science

- o The first workshop, or meeting, on the subject of underwater high-energy radiation studies was held at Western Washington State College in joint participation with the University of Washington. The workshop was sponsored by NOAA/MUS&T and the National Science Foundation. Its purpose was to review and assess underwater cosmic radiation studies (suggested and funded by MUS&T) and to develop a more sophisticated array of detectors for measuring and analyzing certain cosmic and other radiation at great ocean depths. Such a detector (called DUMAND—Deep Underwater Muon and Neutrino Detector) would be multiagency supported and would yield new and basic data on the origin and energies of the radiation. The workshop produced a comprehensive preliminary report in which theoretical concepts were developed.
- o A second multiagency-sponsored (ERDA, NOAA, NSF, and ONR) workshop was held at the University of Hawaii in September 1976. Physics and underwater engineering concepts generated since the first meeting were reviewed. An orderly sequence of deep underwater experiments was defined, and proposed, as precursors to a proposed program by the DUMAND steering committee for a prototype detector array to be deployed off the island of Maui.
- o NASA continued development of a neutron generator for underwater activation experiments. NASA, MUS&T, and other agencies will cooperate in a program of packaging the device for a test program of sea-bottom analysis in Chesapeake Bay.

Interagency activities

- o NOAA/MUS&T support (about one-third of the total annual operating costs) for the *Alvin* submersible continued. Interesting new data on deepwater radioactive substances dump sites, etc., were obtained. New scientific data were also gathered.

International activities

- o In August, September, and October 1975, Project FISSHH was conducted off Rockport, Mass. Important ecological, technological, and fisheries resource data were gathered by German, Polish, and United States science divers, working from the Federal Republic of Germany's underwater laboratory, *HELGOLAND*. This was the first sustained, major, cold-water habitat, saturated-diving mission in U.S. waters. It was an example of a major international cooperative effort, involving divers from the three nations and transport of the FRG's underwater laboratory *HELGOLAND* to the United States by a Polish ship.
- o In June and July 1976, a diving technology, underwater welding, and pollution field study was made off Lubeck, FRG, using the *HELGOLAND*. New data were acquired on welding techniques and the chemistry of pollutants in the marine environment.

Marine Science Application

- o Four deepwater *(Alvin)* missions were conducted, as well as,
- o Four "shallowwater" (i.e., less than 2,000 ft) diving missions. Multiagency participation attended these missions.

Diving, Technology, and Physiology

- o A diving recompression computer was developed by NUC, Hawaii, with NOAA support and field tested by divers, near Lubeck, FRG.
- o NOAA/ERDA support was provided to the Florida Institute of Technology for the training of emergency medical technician/divers.
- o Several meetings and training sessions on recompression techniques and physiology were held.

REQUIREMENTS AND SYSTEMS ANALYSES

The first MUS&T annual report in FY 1972 stated that activities related to program requirements and systems analyses would be in two major areas: 1) Program goals and applications—to include studies of manned undersea activity goals and applications, benefits from manned undersea activities, and regional needs and benefits; and 2) Program evaluations—to include effectiveness and accomplishments of manned undersea activities. The FY 1973 annual report presented the results of a National Academy of Sciences Ocean Affairs Board and National Academy of Engineering Marine Board workshop study on Manned Undersea Activities and results of a University of New Hampshire study of the design and operations requirements for future manned underwater platforms.

During FY 1976 (and the transitional quarter), attention was again given to the two major areas. The Marine Board, Assembly of Engineering, National Research Council, made an assessment of the MUS&T Program. In response to Congressional interest, MUS&T studied requirements for improving its manned underwater technology capabilities to support U.S. underwater scientific, research, and engineering missions leading to the "OCEANLAB" systems concept. Also, in response to Congressional interest in the use of manned submersibles and habitats for undersea science and technology programs, the General Accounting Office (GAO) began a comprehensive audit program to assess the potential of manned underwater activities.

MARINE BOARD REPORT ON MUS&T PROGRAM

In 1975, the National Oceanic and Atmospheric Administration requested the National Research Council to study the support provided by the Manned Undersea Science and Technology Office to U.S. civil manned undersea programs, with emphasis on present and future needs of the user community. The Assembly of Engineering, Marine Board, formed a panel on undersea facilities to undertake the study. The study is an extension of a 1972 examination of civil manned undersea activity in relation to national needs conducted by the Marine Board and Ocean Affairs Board (now Ocean Sciences Board), which produced the report, *Civil Manned Undersea Activity: An Assessment.* The 1972 study appraised the need for all civil manned undersea activities within the national ocean program. The second study addresses the need and scope of a civil manned undersea science and technology program within the Federal Government, with emphasis upon MUS&T's role in NOAA. In the study, the panel considered:

- Products and services provided by MUS&T.
- The need for, and use of, capabilities and services provided by MUS&T to Government agencies and other users.
- The need for engineering research and development to increase the capability and safety of existing and proposed undersea facilities.
- The program balance between service and research functions, and between national and international agreements on MUS&T operations.

The panel noted that the functions supported by MUS&T are a mixture of scientific research and technology, combined with diving, submersible, and habitat operations. The functions of MUS&T identified by the panel during its study are:

1. Providing undersea facilities, including both submersibles and habitats;
2. Initiating and/or supporting manned undersea science and technology programs;
3. Developing diving safety standards for NOAA;
4. Fostering international cooperation in manned undersea science and technology projects;
5. Coordinating national undersea science and technology programs;
6. Establishing standards and criteria for manned undersea systems;
7. Funding key/limiting technical problems in manned undersea science and technology; and
8. Providing for information and data exchange in the foregoing areas.

Some of the panel's salient comments and conclusions follow.

The panel sees a need to "continue and strengthen the coordination of federally sponsored civil manned undersea activity." Panel recommendations included the following:

"The MUS&T program should be national in scope and should support civil Federal and nonFederal users."

"The principal thrust should be one of coordination and overall management rather than operational control" with the objectives emphasizing:

- Providing a national focus in the area of civil manned undersea programs through a long-range planning effort, both nationally and internationally;
- Providing information and services on a national basis to include diving tables, statistics, and initiation of standards;
- Transfer of research results and technology between government agencies, industrial organizations, and academic institutions, and
- Providing funding grants, within specified guidelines, for the development, application, testing, and support of undersea activities.

The panel commented favorably on MUS&T's efforts in diving safety and standards, particularly publication of the *NOAA Diving Manual.* It concluded, with respect to the Federal effort to initiate a national plan for the safety and health of divers—which MUS&T helped start with NIOSH—that "MUS&T, through its position, experience, and present responsibilities, could be a principal focus for the coordination of the plan." The panel further indicated that "NOAA should continue to support specific developments which ensure and promote safety in undersea activities."

In general, the panel's report provides the consensus and basic information to assist the MUS&T Office improve and extend operations, and provide for the needs of various user communities as these develop. The panel suggested that MUS&T broaden the base of its proposal and project review procedures. This is being done by establishing new and more representative review panels and boards for the various disciplines which MUS&T supports, or plans to support.

"OCEANLAB" PROGRAM ACTIVITIES

During 1975, NOAA's Northeast Fisheries Center (NEFC) in Woods Hole, Mass., in connection with fisheries research related to the International Commission on Northwest Atlantic Fisheries (ICNAF), established requirements for saturation diving missions during the study of herring spawning and hydroacoustics off the coast of Rockport, Mass. As noted in the 5-year summary section, MUS&T has supported NEFC research that required manned undersea missions involving submersibles, both observational and lockout, and surface support diving. These studies indicated that an "advanced capability" underwater laboratory was necessary for further and more extensive research missions. None of the three available U.S. habitats *(HYDROLAB, LA CHALUPA,* and *AEGIR)* was capable of operating in the rougher, colder New England waters at a depth of about 105 ft. As described under Project FISSHH in the International section of this report, the German underwater laboratory *HELGOLAND* was transported by the Polish Fisheries Central Board to Rockport, Mass., and the mission was completed in December 1975.

As a result of congressional interest in manned underwater research (including site visits to ongoing MUS&T-sponsored missions— Project SCORE, using the Perry *HYDROLAB,* and Project FISSHH) much discussion was generated concerning the availability of U.S. manned underwater research facilities for similar advanced missions. In response to a Congressional request, MUS&T prepared a report titled "Concept Paper for the Development and Utilization of an American Underwater Laboratory, OCEANLAB," December 1975. It was stated that a U.S. system capability, such as the proposed mobile undersea laboratory, be developed because of the inadequacy of available U.S. facilities, and the need to develop and rationally use offshore oil, gas, mineral, and fishery resources further offshore in hostile waters.

At the House Appropriations Subcommittee Hearing on NOAA's FY 1977 budget, the "OCEANLAB" concept was discussed and is reported in the Committee on Appropriations print—Hearings before a Subcommittee of the Committee on Appropriations, House of Representatives, Ninety Fourth Congress, Second Session, February 9, 1976.

As a result of this Congressional initiative, the MUS&T group studied possible applications for an "OCEANLAB"-type facility and refined the system characteristics stated in the December 1975 Concept Paper. For example, it was established that the costs for technology providing a diving-lockout capability to depths of 1,000 ft might not be appreciably greater than those for 300 ft, while providing many additional missions.

In July 1976, Congress passed Public Law 94-362, which included an appropriation of $1,500,000 for "OCEANLAB." The wording of the bill, HR 14239, was: "Providing further, that of the amount herein appropriated $1,500,000 should be available for studies (including surveys, mission analyses, test analyses, and initiation of a design and engineering study) for an underwater ocean laboratory." The Senate Report (No. 94-964) that accompanied HR 14239 stated: "The Committee has included $1,500,000, the same amount as included in the House bill to allow the Manned Undersea Science and Technology Office to support surveys, mission analyses, cost analyses, and initiation of design and engineering studies for an underwater ocean laboratory. Funds are also included for training, diver physiological analyses and continuation of ongoing programs in this area. The purpose of such a laboratory would be to provide a national underwater ocean habitat for research related to living and nonliving marine resources. Testimony reaching the Committee indicates that the OCEANLAB as proposed by NOAA would be the focal point for programs to utilize diver-scientists to study and assess the fish stocks of the Continental Shelf.

The waters adjacent to New England, some of the most prolific in terms of living resources in the world, have been seriously overfished in the past few years by foreign fisheries. With the adoption of the 200-mile jurisdiction zone, the United States must be prepared to assure that the remaining fish stocks are allowed to increase to levels that will sustain a maximum U.S. fishery production."

During the 1976 transitional quarter, MUS&T initiated a procurement for a preliminary system design cost and schedule study of a mobile underwater laboratory system based on the OCEANLAB concept. This concept calls for a national, mobile underwater facility that can function as a manned engineering and science laboratory at various depths and locations to aid and enhance the advanced diving technology needed to develop offshore sources of energy, obtain information for marine resource management, and provide the knowledge needed to develop and verify safety standards and requirements.

The objective of this study effort is to obtain information concerning costs and schedules for the complete design, development, construction, test, and evaluation of a mobile underwater laboratory system. The successful contractor will perform a systems engineering study based on "OCEANLAB" system performance requirements and major subsystem operating characteristics provided by NOAA. These requirements and characteristics have been based on preliminary surveys and mission analyses of potential users.

In the last part of the transitional quarter, the MUS&T Office began a series of preliminary user survey workshops to ensure the widest possible use involvement in establishing the ranges of design and operational parameters such as environmental constraints, vehicle performance, life support, laboratory space, mission instrumentation, surface/shore support, navigation, communication, power, emergency capabilities, and data management. The assistance of NOAA Sea Grant's Marine Advisory Service and the NOAA Woods Hole NEFC group, as well as other Federal agencies, was solicited. The results of the contract effort will be available in FY 1977. The system program definition phase will begin in FY 1977. This system program definition will result in: a detailed technical development plan; firm performance specifications; detailed cost analyses for design, development, test, and evaluation; life cycle costs; and requirements for operational logistics and maintenance.

GENERAL ACCOUNTING OFFICE AUDIT PROGRAM

During the 1977 transitional quarter, as a result of the Congressional interest in manned undersea research mentioned above, GAO initiated an audit program on the use of manned submersibles and habitats for progressive activities in undersea science and technology. As stated in its initial statement of objectives, "The objective of this review is to find out what has been done in the field of manned undersea research in the past, what is being done at present, and what could be done in the future. We want to determine what the problems of manned undersea science and technology were in the past, what it has achieved or not achieved, and where it may go from here."

The Audit Program covered all manned undersea research programs and projects since 1960. Plans were to examine: all current and projected goals; the role of the Federal Government, academia, and private industry in various programs; technology transfer; major problems of past programs; available manned undersea facilities; technological improvements needed; present limitations on men working underseas; and the need for a Federal manned undersea submersible program. Results of the study are expected by mid-1977.

OPERATIONS EFFECTIVENESS AND SAFETY

NOAA DIVING PROGRAM

Administrative Structure

The NOAA Diving Program is managed by the Associate Administrator for Marine Resources through the Director of the Manned Undersea Science and Technology (MUS&T) Program, who together have the broad managerial responsibility for the program, and through the NOAA Diving Coordinator and his assistants, who have the day-by-day operational responsibility for all diving activities (fig. 4).

The Diving Coordinator is responsible for the training, safety, and certification of all NOAA divers and for working closely with the NOAA Diving Safety Board and NOAA Diving Medical Review Board, which formulate the training and operational policies, medical qualifications, and reporting requirements.

The NOAA Diving Safety Board is the policy-formulating body in the administrative structure. Its recommendations, based on reviews of operating policies, training needs, and operational procedures, and with the approval of the Associate Administrator for Marine Resources, shape the direction of the diving program as it continually changes and expands to meet NOAA's diving needs.

The NOAA Diving Medical Review Board, established by a NOAA Directive on March 8, 1974, is responsible for reviewing the medical qualifications of NOAA divers and diver candidates. It comprises experts in the field of diving medicine. Members of the Board are actively involved in training programs to make NOAA personnel more competent in handling diving medical emergencies. As new knowledge of diving physiology is gained, the Medical Review Board uses this knowledge in its evaluation of the medical criteria that control NOAA diving operations.

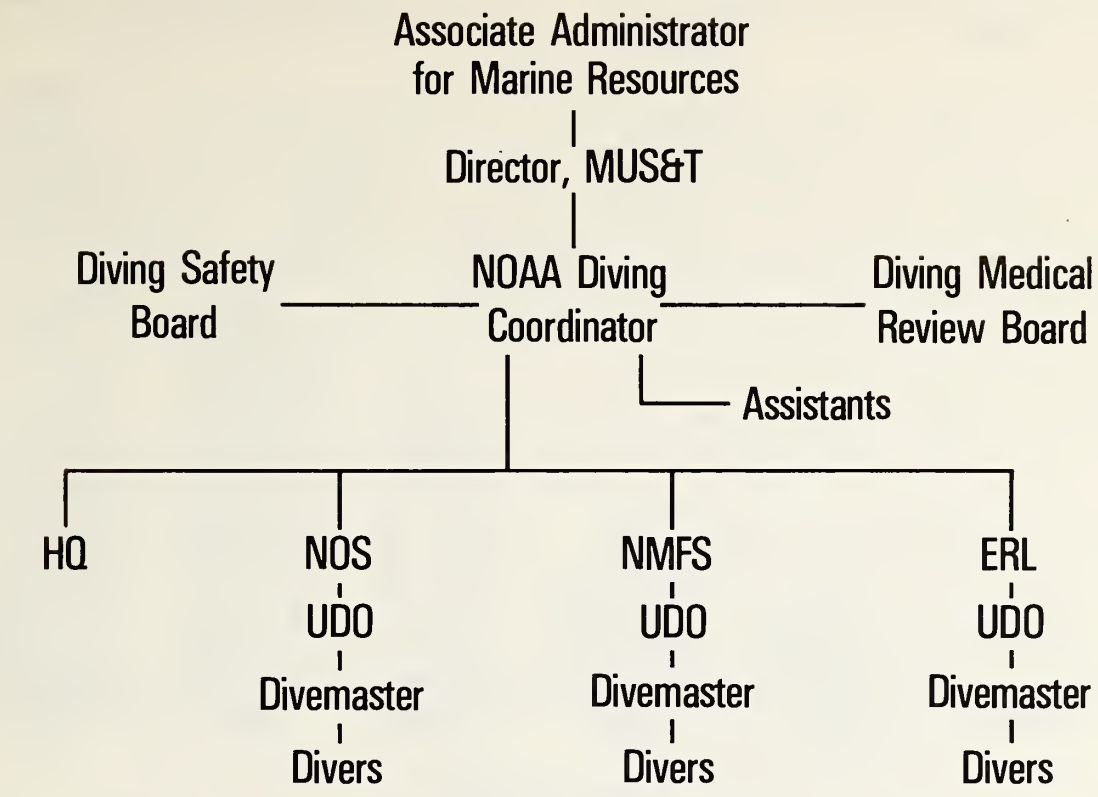
Diving operations in NOAA are carried out to support the missions of NOAA's Major Line Components (MLCs) and Principal Organizational Elements (POEs) as shown in figure 4. Each of NOAA's three MLCs that are actively using diving as an operational tool has a Major Line Component Diving Officer. The MLC Diving Officer represents the MLC on the Diving Safety Board and interacts with the Diving Coordinator by planning, programing, directing, and reviewing the diving activities within the MLC to ensure compliance with overall NOAA policies on underwater operations.

Within each of the MLCs individual units that have diving operations the responsibility for the operations rests with the Unit Diving Officer (UDO). The UDO has direct control of all individual diving operations. The use of NOAA divers for NOAA missions, and the safety and operational efficiency of the dive, depend on the judgment and expertise of the UDO. If the UDO cannot be present for an operation, a competent Divemaster may be a substitute and discharge the same responsibilities.

NOAA Divers

The number of divers in NOAA has increased since 1970. At the beginning of FY 1976, 374 divers (fig. 5), were certified in one of NOAA's three levels of diver certification—53 as trainee divers, 227 as limited divers, and 94 as unlimited divers. About one-half are either NOAA Corps officers or fisheries biologists (fig. 6). Most diving activities relate to resource ecology, fisheries management, coastal zone and estuarine studies, ecosystems investigations, environmental conservation and assessment, hydrographic and oceanographic surveying, and vessel and installation maintenance. NOAA divers also assist other Federal agencies such as the Coast Guard and National Transportation Safety Board in search, rescue, and recovery operations.

Most NOAA diving activities are in U.S. maritime areas, including Alaska, Hawaii, and the Great Lakes. Most NOAA fleet vessels have a complement of divers (officers or crewmen) aboard, and most National Marine Fisheries Service (NMFS) centers, laboratories, and field stations have resident divers. Diving is a collateral voluntary duty in NOAA, generally performed by qualified individuals whose primary occupation is enhanced by such duty.



Legend

UDO – Unit Diving Officer
NOS – National Ocean Survey
NMFS – National Marine Fisheries Service
ERL – Environmental Research Laboratories
HQ – Headquarters

Figure 4.—Administrative structure of NOAA Diving Program.

NOAA Diving Manual

A special achievement of the NOAA Diving Program was the development and publication in 1975 of the *NOAA Diving Manual*. The Manual is authoritative reference for NOAA's scientist, and working divers, and also has broad appeal and usefulness for the entire diving community. It contains basic information and data on applied diving technology, including that needed to carry out scientific investigations and many tasks of the working diver.

The Manual is concerned mainly with shallow-water diving (to 300 ft), the depth range in which NOAA divers normally operate. It supplements the *Navy Diving*

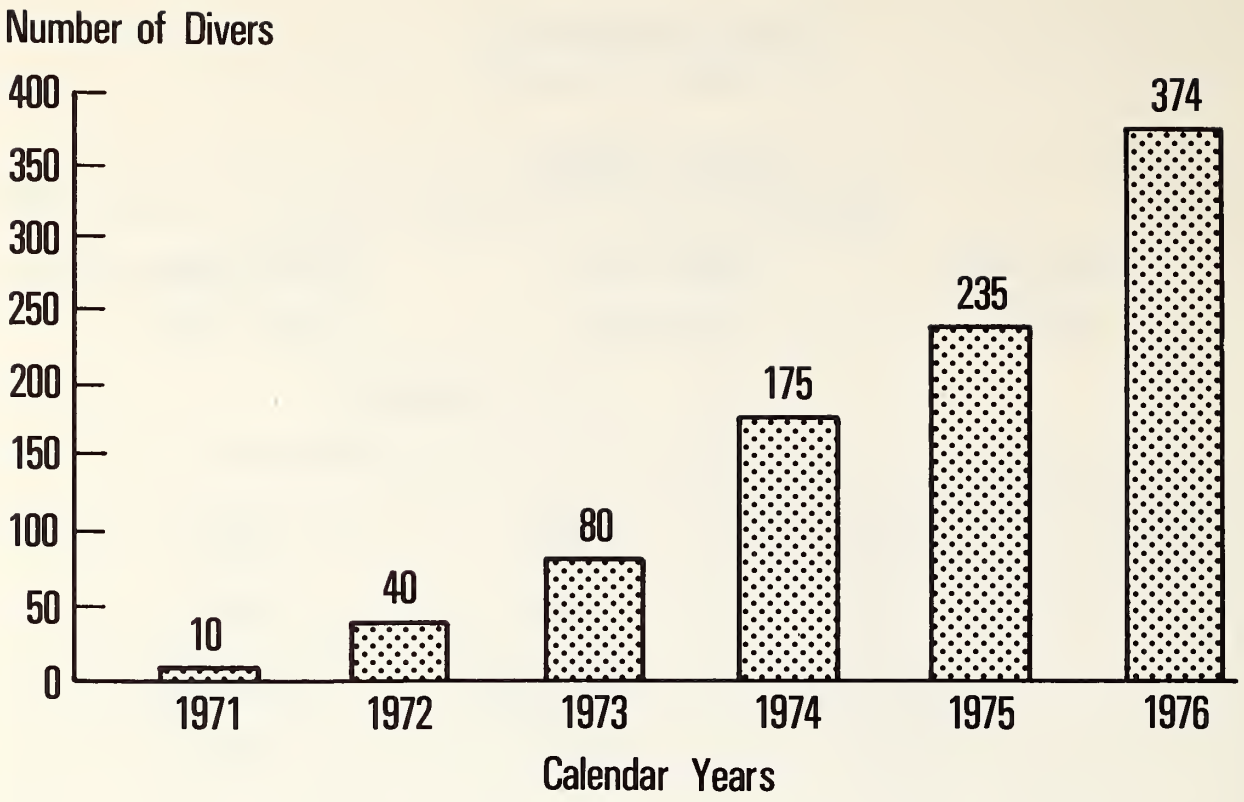


Figure 5.—Increase in NOAA divings, 1971-76.

Manual and incorporates sections of the *Navy Diving Operations Handbook* that apply to deeper mixed-gas diving procedures.

The Manual provides NOAA and non-NOAA scientists and working divers with the latest advances in diving physiology, hyperbaric medicine, underwater scientific methodology, and information on newly developed gear and operational techniques. It is now used, with the *Navy Diving Manual,* as a reference in the *OSHA*[1] *Standard for Diving Operations,* which is proposed to be the Federal law for the diving industry. Because applied diving technology changes rapidly, the *NOAA Diving Manual* will be periodically revised to keep up with the state-of-the-art.

NOAA FY 1976 Operational Dives

Most operational dives during FY 1976 were performed by diving personnel in three of NOAA's six major line components (MLCs)—the Environmental Research Laboratories (ERL), the National Marine Fisheries Service (NMFS) and the National Ocean Survey (NOS). Diving log data indicate the level of NOAA diving activity for these MLCs in terms of number of dives and bottom time, and by types, depth ranges, and purpose of dives (table 1).

Most NOAA dives use "open-circuit scuba," breathing compressed air. When environmental conditions warrant, or subsurface time requires it, NOAA divers use surface-supplied equipment for their tasks. Virtually every type of diving platform and facility—ships and boats, habitats, recompression chambers, and swimming pools—is used for NOAA operational and training dives. During saturation diving missions, NOAA divers live in sea-floor habitats, such as the *HELGOLAND* underwater laboratory, which was used for 177 saturation excursion dives during Project FISSHH in the Gulf of Maine. Operational dives were made in a variety of environments, including Bering Sea ice flows, ocean dumpsites in the New York Bight, and the silty outflow of the Mississippi Delta (fig. 7).

[1]Occupational Safety and Health Administration, U.S. Department of Labor

Table 1.—NOAA FY 1976 Diving Activity by NMFS, NOS, and ERL

Major line component	Dives and bottom time		
	Number of dives	Percentage of total	Bottom time
NMFS[1]	3,414	62.8	1772h 33min
NOS[2]	1,653	30.4	809h 39min
ERL[3]	368	6.8	130h 12min
Totals	5,435		2,712h 24min

Types of dives

Nonsaturation	4,918
Saturation	177
Saturation-support	340

Depth ranges of dives

0-33 ft	2,261
34-66 ft	1,671
67-99 ft	596
100+ ft	907
Total	5,435

Purpose of dives

Purpose	Dives	Percentage
Biological survey	1,894	34.8
Geological survey	167	3.1
Oceanographic survey	136	2.5
Physiological	14	0.3
Maintenance and repair	1,151	21.2
Search and recovery	226	4.2
Test and evaluation	146	2.7
Training	780	14.3
Recreation	921	16.9

[1]National Marine Fisheries Service.
[2]National Ocean Survey.
[3]Environmental Research Laboratories.

U.S. UNDERWATER FATALITY STATISTICS STUDIES

The primary source of initial information is a newspaper clipping service. However, URI also is alerted to fatalities through Coast Guard search and rescue reports, cooperating local officials, and cooperating individuals. Report forms, developed through an American National Standards Institute Committee, are sent to individuals who, from newspaper reports, appear to have information on the accident, and to local police, coroners, and similar officials. When an autopsy is performed, a copy of the report is requested. Information on each case is compiled into one report form. At the end of the calendar years data from the forms are analyzed to develop a summary report.

The College of Engineering at the University of Rhode Island (URI) has studied diving fatalities in the United States since 1970. This work has been funded since FY 1972 by a grant from NOAA's Manned Undersea Science and Technology Office and the Underwater Safety Office of the U.S. Coast Guard. This joint support is continuing because national concern for diving safety is increasing. The purpose of the effort is to collect statistical information on fatal diving accidents. Such information will be useful to Federal agencies and other organizations that have diving responsibilities, diver training organizations, equipment manufacturers, and others attempting to improve diving safety.

Table 2 summarizes the nature of diving fatalities investigated through these studies for the past 5 years. NOAA's estimate of the size of the diving population in this country is 1,909,000, with about 250,000 new sport divers being trained each year (*An analysis of the Civil Diving Population of the United States, 1973*). When this growth rate and the essentially constant number of fatalities shown in table 2 are considered, it appears that the annual fatality rate for the sport of diving is decreasing.

Table 2.—Summary of diving fatalities, 1970-74

Activity	Fatalities									
	1970		1971		1972		1973		1974	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Scuba diving, nonprofessional	101	8	106	7	107	12	113	6	126	15
Scuba diving, professional and semiprofessional	3	0	1	0	1	0	4	0	4	0
Scuba diving, record attempt	0	0	0	0	1	1	0	0	0	0
Skin diving	26	3	17	0	15	1	23	1	26	1
Diving with surface-supplied air, professional and semiprofessional	4	0	2	0	2	0	5	0	8	0
On-duty military*	0	0	0	0	0	0	0	0	2	0
Compressed air explosion	0	0	0	0	1	0	0	0	1	0
Totals	145		133		139		152		183	

*One Coast Guard and one Navy diver.

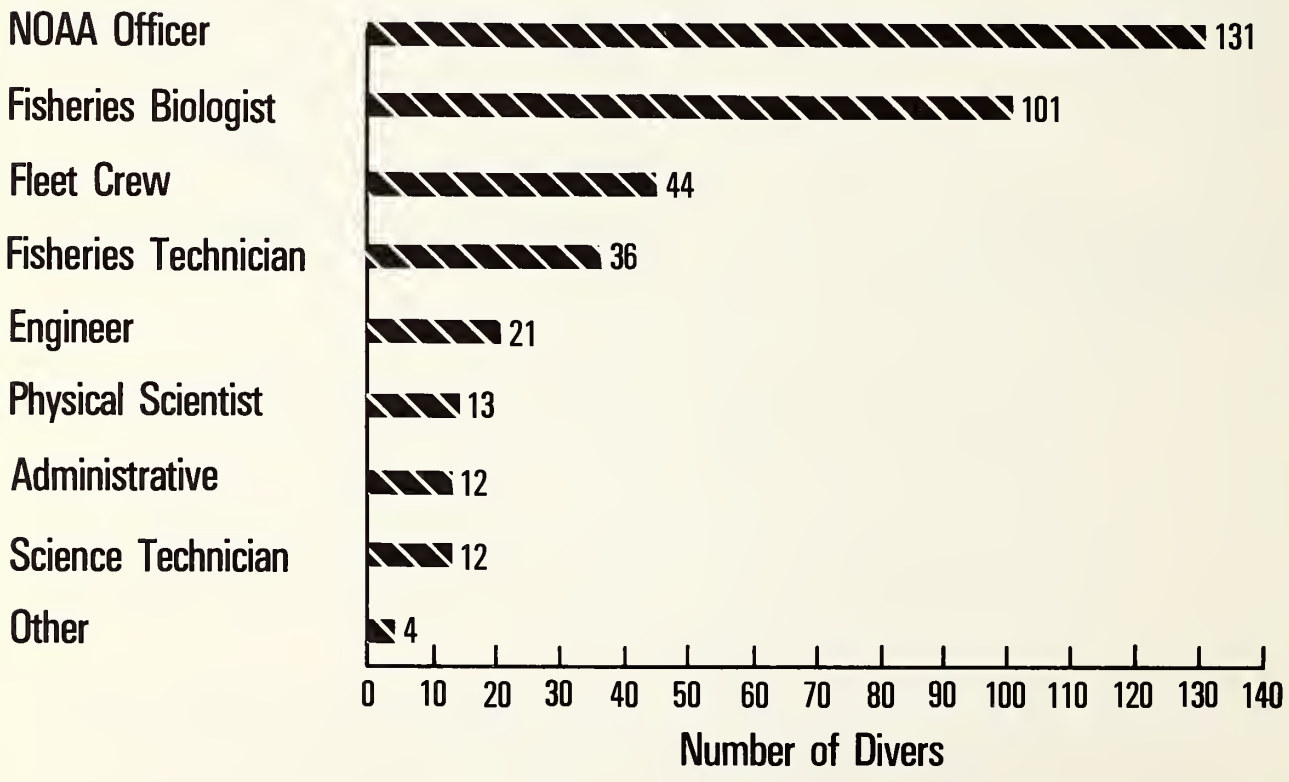


Figure 6.—Occupations of NOAA divers, 1976.

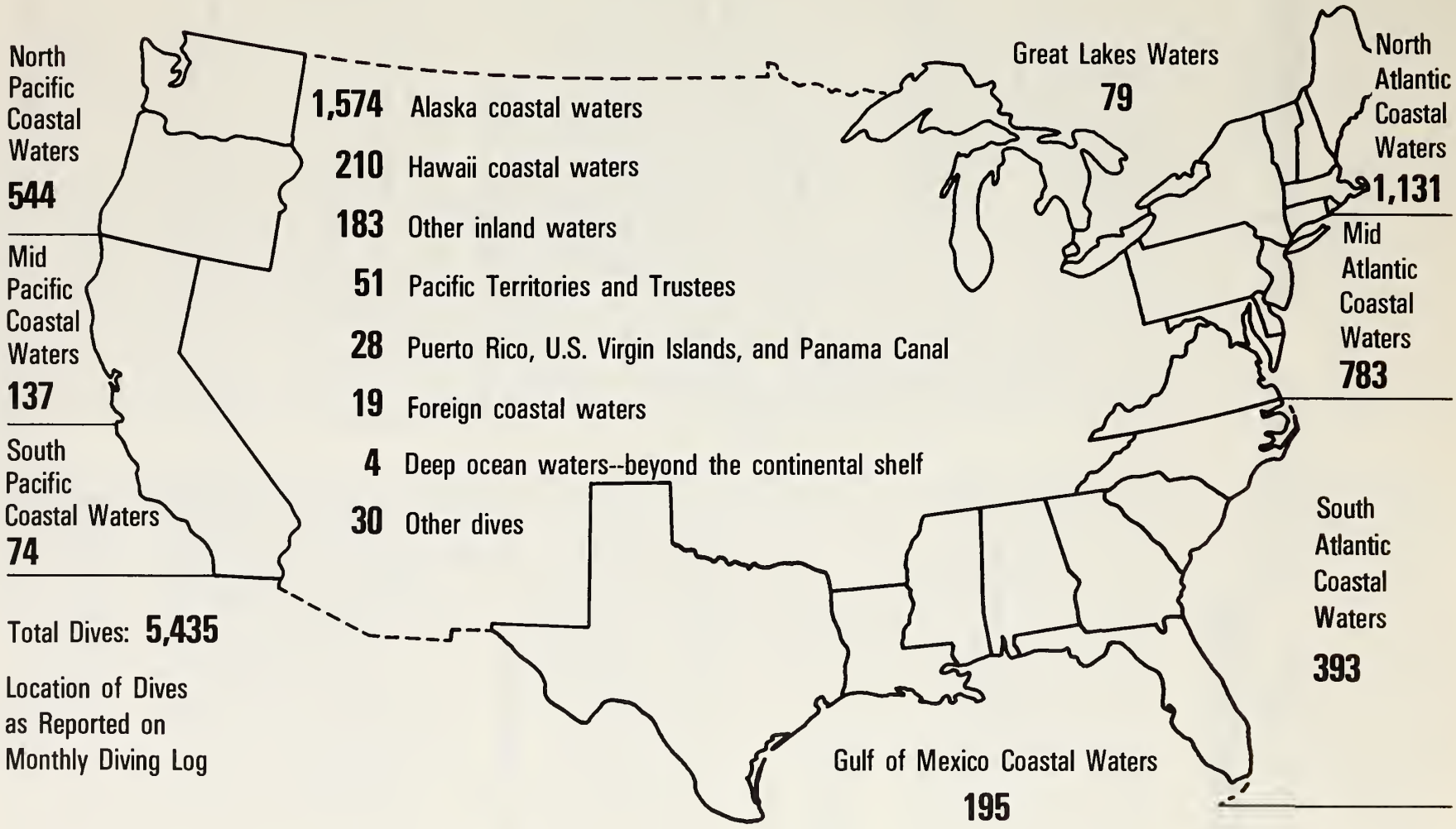


Figure 7.—NOAA dives in U.S. and foreign waters, FY 1976.

TECHNOLOGY STUDIES, DEVELOPMENT, AND TRANSFER

The MUS&T concern with underwater technology consists mainly of following the progress and status of technology in other agencies and in institutions, industry, and other countries. An annual survey is made of the civilian use and status of both U.S. and foreign underwater facilities—submersibles and habitats.

Through interagency (ICMSE) interest, and joint interagency and international missions, some projects with modest funding were carried on during FY 1976. Their descriptions follow.

DIVING TECHNOLOGY

Bubble Detectors

Background. Inert gas* in the breathing medium of a diver is absorbed or eliminated by the diver's body tissues, during descent and ascent, in accordance with Henry's law.** The concentration of the inert gas in the tissues is a function of the depth and duration of the dive. If certain depth/time dive profiles are exceeded, decompression of the diver is required in order to prevent, to the greatest extent possible, the occurrence of decompression sickness, or the "bends." Decompression is carried out in accordance with appropriate decompression schedules.

Evaluating diver decompression schedules for safety against both short- and long-term physiological changes is a difficult task. Most schedules are relatively conservative and give most individuals a reasonable margin of safety against decompression sickness. However, because of wide variability among individuals, a given schedule can be extremely safe for some, but only marginally safe for others. Also, individual tolerances to decompression vary significantly with time and diving history, so a given schedule may not always have the same results for a given diver. Consequently, an evaluation based upon a small sample of divers and/or upon only a few applications of the schedule may not provide highly reliable results.

Observations of the frequency and severity of decompression sickness symptoms alone may not be a particularly sensitive way of assessing overall safety. Evidence indicates that bubbles can generally be detected in the bloodstream prior to, and often with the subsequent absence of, decompression sickness symptoms. It is possible that such bubbles are more directly related to causes of long-term effects such as aseptic bone necrosis than they are to symptoms of the bends. Consequently, monitoring blood flow for bubbles may be significantly useful in evaluating decompression schedules.

Technology. Two techniques for bubble detection have been applied— by Westinghouse Electric Corporation and by the University of Washington Applied Physics Laboratory, under U.S. Navy contracts, with some NOAA support.

When an ultrasonic sinusoidal pressure wave propagates through a two-phase mixture such as bubbles in human tissue, the highly nonlinear gas compliance at the bubble interface causes point sources of primary wave distortion. The distortion of the primary sinusoidal wave produces harmonics that can be received and used as a very sensitive indicator of bubble presence. This is called the "nonlinear ultrasonic propagation technique." It is not sensitive to blood flow rate and corpuscular movement, is applicable equally to moving and stationary bubbles, operates at low input energy levels, and is insensitive to subject motion with regard to harmonic generation. Tests have demonstrated that the technique can detect bubbles within both the venous and the capillary system, at a low power level, and well before the diver is aware of symptoms.

The second technique uses the Doppler frequency-shift principle for bubble detection. Two bubble detectors using this principle were compared in field tests at Duke University during chamber verification for the SCORE mission decompression schedule. Tests showed that the two major problems encountered with both Doppler units were the positioning of the Doppler probe to get a good signal from every diver and the high background noise. The quality of the signal depends strongly on proper positioning of the probe, and the best position varies from diver to diver. However, it appears that the signal is enhanced when a sitting diver bends

*Nitrogen is fairly inert; helium, argon, krypton, and neon are totally inert.

** Henry's Law states that "The amount of any given gas that will dissolve in a liquid at a given temperature is a function of the partial pressure of that gas in contact with the liquid and the solubility coefficient of the gass in the particular liquid."

forward at the waist or stands up, and is poor when the diver is supine.

Work on these two types of bubble detectors is continuing. Their successful application in diving operations will be a significant advance in diving technology.

Digital Decompression Computer

A digital decompression computer to be worn on a diver's wrist has been developed by the Naval Undersea Center's Hawaii Laboratory under a grant from NOAA. The computer monitors the diver's depth and dive time and gives a continual display of his decompression status. A prototype was demonstrated early in FY 1975. Some diver-worn units were to be ready for field testing and evaluation in FY 1976.

The decompression computer comprises four principal electronic subsystems: a pressure transducer, an electronic "clock," a programable read-only memory (PROM) storage, and a digital information display. The pressure transducer measures the diver's depth while the electronic clock monitors the diver's time. The two signals are used as inputs to the PROM, which is programed with a mathematical model for inert gas absorption. The computer uses the time and depth inputs to calculate the diver's decompression status continuously, even in multidepth or repetitive dives not covered by the standard decompression tables. The readout on the computer consists of two digital light-emitting diode displays. One tells the diver the depth and the other the safe-ascent depth, the depth to which he can safely return with decompression. The unit can be converted for mixed gas diving using a PROM that is programed for the gas mixture used.

The computer can easily compute the gas absorption of seven different tissues, compared with present decompression meters that use three tissues for computation. These meters work by measuring the pressure of the gas as it diffuses through a tissue-simulating membrane. They are subject to error, especially if poorly maintained or roughly handled. The wrist-worn digital decompression computer was demonstrated in October 1974 to the Navy's Experimental Diving Unit and to MUS&T. Several simulated decompression dives were found to exactly match the standard decompression tables. The unit also was used to run a simulated, 3-day saturation mission, using excursions that were encountered during SCORE of the Bahama Banks Research project.

Three of the prototype units were field tested during the US/FRG Lubeck II saturation mission in the Baltic Sea during July 1976. (See International Activities.) The digital decompression computer is an advance in the use of electronics to monitor free-swimming divers.

Portable Inflatable Recompression Chamber (PIRC)

Cost, weight, and bulk have prevented wider use of recompression chambers by recreational divers, and sometimes by military and NOAA divers in difficult or remote diving locations. Consequently, the U.S. Marine Corps, U.S. Navy, and NOAA are funding the development of a small PIRC that is cheaper and lighter than traditional chambers. The PIRC can be packaged and easily transported by air. The Naval Undersea Center has built a prototype PIRC and has established certification requirements.

The recompression chamber consists of a cylindrical body manufactured from a Kevlar fiber-rubber composite. Kevlar is a new high-strength organic compound that has been used for cables and bulletproof vests. The door of the chamber is a specially designed leakproof "zipper." The chamber will withstand an internal pressure of 75 psi or the equivalent of 165 ft of seawater. When inflated it will be 30 in. in diameter and 90 in. long, which will allow it to hold the patient and a medical attendant. The entire chamber can pass through standard double-lock recompression chamber doors so that the patient can be directly transferred to a larger, more complete facility. When not in use, the chamber can be collapsed to fit into a 36 by 8 by 8-in. carrying container. The chamber will weigh about 50 lb, and will use standard scuba tanks for its pressurization and life support. A high-efficiency recirculating device will circulate the chamber air through a CO_2 scrubber, allowing a single 72-cu ft^3 scuba tank to provide life support for about 1 hour. Tests and evaluations of the chamber are continuing at the Naval Undersea Center's Hawaii Laboratory.

UNDERWATER WORK—WELDING

Underwater experiments using different welding techniques were performed during the second joint US/FRG program in the Lubeck area. (See International Activities—US/FRG Lubeck II.)

RESEARCH SUBMERSIBLES AND HABITATS

Submersibles

Major applications of submersibles are for baseline environment measurements; monitoring and assessment of areas planned for ocean dumping, undersea mining, oil and gas production activities, development of offshore powerplants and offshore deep-water structures; and for fisheries research and management. Additionally, submersibles have been used in salvage operations, sediment transport studies assessing the fate of pollutants and bottom nutrients, and in test and evaluation of new marine instrumentation. In some research, submersibles are the best means available for detailed examinations and sampling of deep ocean features.

Because of the nature of the environment the safety of the occupants of submersibles requires utmost precautions. Safety can be considered in two major components: accident prevention and rescue/recovery capabilities. These components are addressed by

procedures covering the construction and use of submersibles. Classification or certification codes and published reports such as those produced by the Undersea Vehicle Safety Standards Subcommittee of the Marine Technology Society[1] are doing much to ensure that safety is being considered in the design, building, testing, and operation of manned undersea vehicles.

The total number of U.S. submersibles reported available in 1976 has decreased to 28 compared to 29 reported available in 1974. Significant changes have occurred, however, within these inventories of the submersibles appearing in the 1974 inventory, *Deepstar-2000* has been sold to France, *TS-1* sold to England, *PC-17* was never built, *PC-18* was built for and is owned by France, *PC-3B* is in storage, and the status of *Sea Ray* is unknown. The following vehicles have been included in the 1976 submersible inventory (table 3): *ARMS* (tethered vehicle), *DOWB, NR-1* (nuclear, U.S. Navy-owned and operated), *PC-14C-2,* and *PRV-2* (lockout capability).

As of September 1976, 20 are considered operational. Six vehicles in the inventory are owned and operated by the U.S. Navy. *Beaver, Johnson-Sea-Link I* and *II,* and *PRV-2* have a diver lockout capability; *DSRV-1* and *2* are capable of a dry transfer of personnel. *Arms, Guppy,* and *Opsub* are tethered submersibles.

The focus of virtually all industrial submersible activity is in European waters, particularly the North Sea. Industrial submersible operations in U.S. waters are negligible compared to those in Europe. The most active U.S. operator in terms of dive-days and excluding the military is the Harbor Branch Foundation. Harbor Branch was responsible for conducting 35 percent of all the dive-days in the United States during FY 1976; most of this activity was centered in Florida continental shelf waters. A summary of the status of the international submersible inventory appears in table 4.

Activities of 11 U.S. submersibles whose dive programs have been reported for the time period July 1975 to September 1976 are listed in table 5. One submersible, *Sea Ranger,* is reported as operational, but made no dives during FY 1976. No data were received on the activities of *Star II.* Of the 888 dive-days logged in FY 1976, 57 were lockout dives; all were performed by Harbor Branch Foundation in *Johnson-Sea-Link I* and *Johnson-Sea-Link II.* Maximum lockout depth was 180 m.

The funding sources of civilian manned undersea activities conducted in the United States during FY 1976 are identified in table 6. The foundation-funded *Johnson-Sea-Link I* and *II* accounted for 35 percent of the total dive-days during this time period; followed by Federally funded activities, which financed 32 percent of the dive-days. Private industry funded 29 percent of the dive-days performed in the United States; academic institutions (Texas A&M's *Diaphus*) accounted for the remaining 4 percent.

In FY 1976 and the 1976 transitional quarter, civilian submersibles in the United States accounted for 498 operational dive-days, during which 888 dives were made. The major mission categories for U.S. submersibles during this period were biological applications, geological applications, inspections, and test training.

Civilian ICMSE[2] agency utilization (282 dives, 142 dive-days) accounted for 32 percent of the total dives and 29 percent of the total dive-days in the report period. Federally funded use (excluding purely military missions, but including ICMSE—301 dives and 161 dive-days) represented 34 percent of all dives and 32 percent of the dive-days. Table 7 and figure 8 show the overall civilian submersibles mission categories.

Habitats

Habitats have been used to house and support scientific divers, especially those operating in a saturated mode for in-situ studies on or near the bottom. They are particularly advantageous for continuous observation and monitoring of processes. Although still referred to by the term "habitat," they have evolved into effective underwater laboratories that include sophisticated experimental instrumentation, as well as living space.

Only one habitat, *HELGOLAND*, was active during the FY 1976. *HELGOLAND*, owned and operated by Gesellschaft fur Kernenergieverwertung in Schiffbau und Schiffahrt, mbH, of West Germany, was involved in two international saturation diving programs sponsored by the MUS&T Office. The First International Saturation Study of Herring and Hydroacoustics (Project FISSHH) was made on Jefferys Ledge in the Gulf of Maine in water depths of 34m. During this operation, 164 man-days (41 team-days) of bottom saturation time was logged. The second *HELGOLAND* project, Lubeck II was conducted during the summer of 1976 in the Baltic Sea in 16 m of water and accounted for 84 man-days (28 team-days) of bottom saturation time for scientific purposes. The mission objectives of Lubeck II primarily involved biological and pollution research; FISSHH was a fisheries program concentrating on herring research.

By way of contrast, in FY 1973, 500 man-days of habitat utilization were for biological purposes alone, 207 man-days for fisheries and 25 man-days for pollution research. About 1,100 man-days of saturated diving for research purposes were accomplished in FY 1973.

The entire U.S. inventory of habitats comprises nine facilities. *LAKELAB, PORTALAB,* and the University of Wisconsin and State University of New York's underwater laboratories cannot maintain saturated diving programs. *EDALHAB* and *TEKTITE* are presently inactive and on display. Of the three remaining habitats,

[1]The Undersea Vehicle Safety Standards Subcommittee of MTS is preparing a third book in a submersible safety series entitled, "Recommended Safety Standards for the Operation of Undersea Vehicles." This study is jointly funded by the NOAA/MUS&T Office, Coast Guard, and the Navy.

[2]Interagency Committee on Marine Science and Engineering utilization by mission category in the United States for the report period. This information was synthesized form table 5, which presents the mission categories of each U.S. submersible whose activities have been reported.

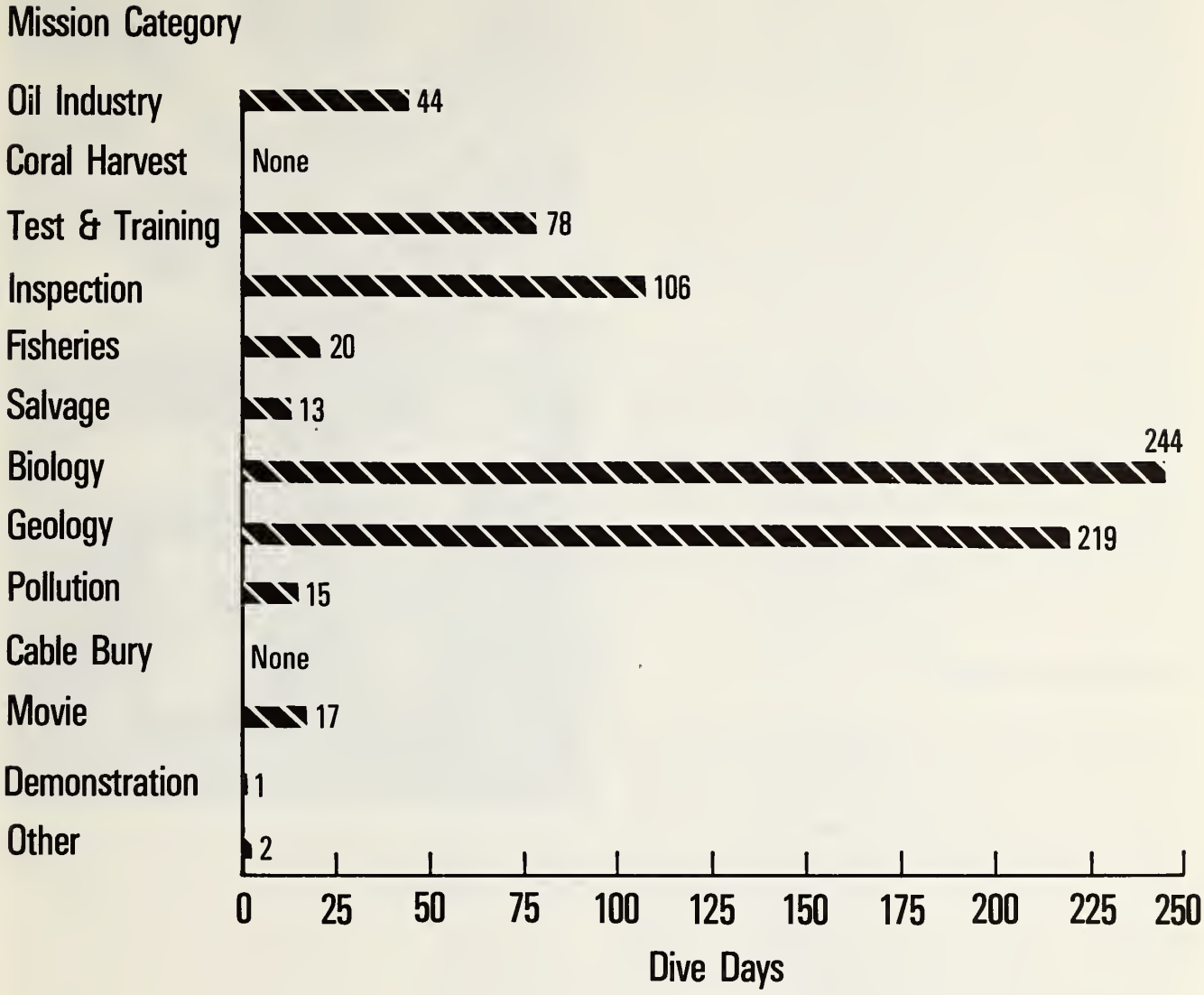


Figure 8.—Civilian submersible utilization in the United States, July 1975 to September 1976.

LA CHALUPA would require extensive financial resources to refit. *AEGIR*, now owned and operated by the University of Hawaii, is capable of future service, but would require some ballast piping replacement and additional repairs to the hull and support structures to make the system operational. The pressure vessels of *AEGIR* are reported in operating condition. *HYDROLAB* is presently on standby status off Lucaya Beach, Freeport, Bahamas, and is considered to be in condition for saturation diving operations, making it the only U.S. habitat readily available for use. The status of these habitas is given in table 8.

There are 12 habitats in the international inventory (these include the U.S. habitats *LA CHALUPA, AEGIR,* and *HYDROLAB*). Habitat ownership by country is as follows: Bulgaria 1, Canada 1, Czechoslovakia 1, Federal Republic of Germany 2, Japan 1, Poland 1, USSR 2 (one of which is under construction), and United States 3.

In FY 1976, no long-term habitat program, such as the Bahama Banks Research Program of 1972-75, was initiated, The MUS&T Office sponsored two programs in 1976 that used the West German habitat *HELGOLAND*. These programs accounted for 248 man-days (69 team-days) of bottom saturation time for scientific purposes. Of this total, 164 man-days (41 team-days) were for fisheries (herring) research, 56 man-days (28 team-days) for pollution research, and 28 man-days (21 team-days) for biological research.

ADVANCED CONCEPTS

Advanced concepts in underwater engineering and physics discussed or studied during the year include:

(a) Further refinements in the technology, electronics, and configuration, of the DUMAND (Deep Underwater Muon and Neutrino Detector) scheme. The detector configuration for DUMAND—consisting of a massive cubic matrix of photomultiplier detectors, emplaced at great depths in the ocean—was first proposed and discussed during a physics conference on underwater research at the University of Utah in 1973. (See under Interagency Activities.)

(b) A variety of logistic, design, and science application problems associated with a mobile undersea laboratory were studied and evaluated as a prelude to funding a preliminary systems design study for an ocean laboratory.

(c) Discussions were held with British and U.S. marine engineers regarding the possible adaptation and use of the one-atmosphere armoured "JIM" diving suit for certain NOAA/MUS&T missions. This British suit obviates the need for diver decompression. It has been tested successfully to a depth of 1,000 ft. (fig. 9).

Figure 9.—British one-atmosphere, armored "JIM" diving suit on display.

TECHNOLOGY TRANSFER

A neutron generator was developed by Sandia Corp., supported by NASA Goddard Space Flight Center. It was modified for possible nuclear activation analysis of the ocean bottom and will be adapted for submersible use. (See Interagency Activities.) Ocean bottom surveys of heavy-element (lead, mercury, etc.) pollutants will be possible by the latter part of 1977, with ERDA, NOAA, and other agencies participating.

Table 3—Contemporary U.S. Manned Submersibles

Name	Depth ft/m	Builder	Operator	Status
Alvin	12,000/3,658	Litton Industries, Minneapolis, Minn.	WHOI, Woods Hole, Mass.	Operational
*Arms***	3,000/914	Oceaneering Int., Houston, Tex.	Oceaneering Int., Houston, Tex.	Construction
*Beaver**	2,700/823	North American Rockwell, Seal Beach, Calif.	Int. Underwater Contr., City Island, N.Y.	Refit
Deep Quest	8,000/2,438	Lockheed Missiles & Space, Sunnyvale, Calif.	Lockheed Ocn. Lab., San Diego, Calif.	Inactive
Deep View	1,500/457	NUC, San Diego, Calif.	Southwest Res. Inst., San Antonio, Tex.	Refit
Diaphus	1,200/366	Perry Sub. Bldrs. Riviera Beach, Fla.	Texas A&M Univ., College Station, Tex.	Operational
DOWB	4,500/1,372	General Motors, Santa Barbara, Calif	Southwest Res. Inst., San Antonio, Tex.	Inactive
DSRV 1 & 2	5,000/1,524	Lockheed Missiles & Space Sunnyvale, Calif.	U.S. Navy San Diego, Calif.	Tech/Op Evaluation
*Guppy***	1,000/305	Sun Shipbuilding & Dry Dock, Chester, Pa.	Sun Shipbuilding & Dry Dock, Chester, Pa.	Inactive
*Johnson-Sea-Link I & II**	1,000/305	Harbor Branch Foundation, Ft. Pierce, Fla.	Harbor Branch Foundation, Ft. Pierce, Fla.	Operational
Mermaid II	1,200/366	Bruker-Physik AG, Karlsruhe, West Germany	Int. Underwater Contr., City Island, n.y.	Operational
Nekton A,B,C	1,000/305	General Oceanographics, San Diego, Calif.	General Oceanographics, San Diego, Calif.	Operational
Nemo	1,000/305	Naval Civil Eng. Lab., Port Hueneme, Calif.	Southwest Res. Inst., San Antonio, Tex.	Operational
NR-1	NA	General Dynamics Groton, Conn.	U.S. Navy	Operational
*OPSUB***	1,000/305	Perry Sub. Bldrs. Riviera Beach, Fla.	Ocean Systems, Reston, Va.	Inactive
PC-14C-2	600/183	Perry Sub. Bldrs., Riviera Beach, Fla.	Kentron, Hawaii Huntsville, Ala.	Operational
*PRV-2**	1,000/305	Pierce Submersibles, Bayshore, N.Y.	Minisub Associates, Albertson, N.Y.	Unknown
Sea Cliff	6,500/1,981	General Dynamics, Groton, Conn.	U.S. Navy San Diego, Calif.	Operational
Sea Explorer	600/183	Sea-Line, Inc., Brier, Wash.	Sea-Line, Inc., Brier, Wash.	Operational
Sea Ranger	600/183	Verne Engineering, Inc., Fraser, Mich.	Verne Engineering, Inc., Houston, Tex.	Operational
Snooper	1,000/305	Undersea Graphics, Inc., Torrance, Calif.	Undersea Graphics, Inc., Torrance, Calif.	Operational
Star II	1,200/366	General Dynamics, Groton, Conn.	Deepwater Explorations, Ltd., Honolulu, Hawaii	Operational
Trieste II	20,000/6,096	U.S. Navy	U.S. Navy San Diego, Calif.	Operational
Turtle	6,500/1,981	General Dynamics, Groton, Conn.	U.S. Navy, San Diego, Calif.	Operational

*Lockout

**Tethered.

Table 4—International Manned Submersible Inventory

	Total Vehicles	Total Operational Sea Trials	Total Inactive[1]	Total Under Constr.	Total Refit	Total Standby[2]
Canada	10	5	0	4	1	0
France	22	11	4	5[3]	2	0
Italy	2	1	0	0	1	0
Japan	3	2	0	0	0	1
Netherlands	1	1	0	0	0	0
Sweden	1	0	0	1	0	0
Taiwan	1	1	0	0	0	0
United Kingdom	10	7	0	2	1	0
USSR	8	7	1	0	0	0
USA	28	21	4	2	1	0
Total	86	56	9	14	6	1

[1] Inactive: Has not operated since at least January 1975. Includes "Unknowns."
[2] Standby; In diving condition, but funding unavailable.
[3] Two vehicles are under construction for a French firm.

Table 5—Activities of U.S. submersibles, July 1975 to September 1976

Submersible	Date *mo/d/yr*	Mission	Location of mission	Total number of dives	Number of days diving	Depth *meters*
Alvin	7/8/75-7/16/75	Deep-sea biology	WHOI Bottom Station	3	3	3,644
	7/23/75-8/4/75	Biology/pollution	Atlantic Margin	10	10	2,832
	8/12/75-8/18/75	Geology	Hudson Canyon	4	4	3,418
	8/29/75-9/8/75	Deep-sea biology	WHOI Bottom Station	7	7	3,659
	1/76	Test and training	Caribbean	5	4	1,988
	1/76-2/76	Geology	Cayman Trough	16	16	3,662
	3/76	Inspection	Virgin Islands	14	14	3,610
	4/5/76-4/10/76	Scientific	Puerto Rico Trench	5	5	3,666
	4/17/76	Biology	Bahamas	1	1	2,071
	4/18/76-4/19/76	Training	Bahamas	2	2	2,830
	4/20/76-4/28/76	Inspection and search	Bahamas	6	6	1,196
	6/4/76	Test	Woods Hole Harbor	1	1	20
	6/8/76-7/15/76	Biology/geology	Offshore Mid-Atlantic States	20	16	3,651
	7/23/76	Test	Woods Hole Harbor	1	1	15
	7/29/76-8/3/76	Radioactive waste recovery	Offshore Mid-Atlantic States	5	5	2,805
	8/13/76-8/20/76	Biology	Offshore Mid-Atlantic States	6	6	3,650
	8/31/76	Test and training	Woods Hole Harbor	1	1	20
Diaphus	8/75-8/76	Biological/geological research	Northern Gulf of Mexico	35	20	152

Table 5—Activities of U.S. submersibles, July 1975 to September 1976—Continued

Submersible	Date *mo/d/yr*	Mission	Location of mission	Total number of dives	Number of days diving	Depth *meters*
Johnson-Sea-Link I.....	6/75	Science	Florida	10	6	30-180
	7/75	Training	Florida	15	9	3-22
		Science	Florida	4		21-100
	8/75	Training	Florida	2	6	3-300
		Science	Florida	6		16-240
	9/75	Training	Florida	3	8	19-300
		Science	Florida	9		18-75
	10/75	Training	Florida	2	5	14-20
		Science	Florida	6		26-94
	12/75	Training	Florida	2	3	15-18
		Science	Florida	5		18-63
	1/76	Training	Florida	4	4	18-54
	2/76	Training	Florida	9	11	4-36
		Science	Florida	9		24-48
	3/76	Training	Florida	3	13	5-18
		Science	Florida	13		27-300
	4/76	Science	Florida	14	9	37-300
	5/76	Science	Florida	1	1	38
	6/76	Training	Florida	1	1	3
		Science	Florida	1	1	38
	7/76	Training	Florida	6	6	28-75
	8/76	Movie	Grand Bahama Is.	13	7	3-300
	9/76	Science	Florida	1	1	180
(Of the above 139 dives, 22 were lockout dives to a maximum depth of 63.3 m.)						
Johnson-Sea-Link II	8/75	Training	Florida	2	2	3
	9/75	Training	Florida	2	2	3
	10/75	Training	Florida	7	6	3-303
	11/75	Training	Florida	1	1	3
		ABS certification	Florida	1	1	309
	1/76	Training	Florida	10	4	15-48
	3/76	Training	Florida	4	7	3-130
		Science	Florida	3		3-130
	4/76	Training	Florida	1	3	3
		Science	Florida	2		3-39
	5/76	Training	Florida	8	14	18-41
		Science	Florida	18		39-138
	6/76	Training	Florida	2	15	3
		Science	Florida	26		28-180
	7/76	Training	Florida	3	5	38-65
		Science	Florida	3		42-103
	8/76	Training	Florida	4		3-27
		Science	Florida	7	12	38-131
		Movie	Grand Bahama Is.	9		8-303
	9/76	Science	Florida	16	9	30-301
(Of the above 129 dives, 35 were lockout dives to a maximum depth of 180 m.)						
Mermaid II.....	8/75	Photography	Offshore Mid-Atlantic States	5	3	75
Nekton Alpha.....	6/30/76	Trim & sonar test	Mission Bay, San Diego, Calif.	3	½	7
	6/30/76	Trim & sonar test	Scripps Canyon, San Diego, Calif.	1	½	208
	7/2/76	Work on Exxon platform	Santa Barbara, Calif.	15	8	266

TABLE 5—Activities of U.S. submersibles, July 1975 to September 1976—Continued

Submersible	Date *mo/d/yr*	Mission	Location of mission	Total number of dives	Number of days diving	Depth *meters*
	7/19/76	Union Oil pipeline	Santa Barbara, Calif.	22	6	66
	7/26/76	Recover RCV for Martech	Santa Barbara, Calif.	3	1	250
	7/28/76	Pipeline inspection	Santa Barbara, Calif.	4	2	55
	7/30/76	Recover current meter	Santa Cruz Island	4	1	66
Nekton Beta	6/30/75	Recon wrecked platform	Gulf of Mexico	7	3	78
	8/17/75	Science survey NOAA/MUS&T	East Coast, U.S.	104	30	333
	11/7/75	Coral reef survey	Gulf of Mexico	4	2	120
	1/76	Coral reef survey	Bahamas	34	7	266
	4/20/76	Equipment recovery	Gulf of Mexico	4	2	106
	5/76	Route survey	Gulf of Mexico	11	4	78
	7/76	Pipeline inspection	Gulf of Mexico	31	17	75
Nekton Gamma	6/75	Pipeline inspection	Santa Barbara, Calif.	10	4	41
	6/75	Demonstration dives	San Diego, Calif.	2	1	145
	10/75	Shipwreck survey	Crescent City, Calif.	6	5	60
	12/75	Dam inspection	Los Angeles, Calif.	10	2	94
	1/76	Equipment recovery	Catalina Island, Calif.	15	3	190
	2/76	Dam inspection	Central California	23	8	203
	6/76	Science survey NOAA/MUS&T	East Coast, U.S.	91	46	333
PC-14C-2	6/75-9/76	Search, inspection, and observations	Kwajalein, Marshall Is.	39	37	50-60
Sea Explorer	6/76	Recovery of drowning victim	Seattle, Wash.	3	2	55
	7/76	Cable inspection/ documentation	Long Island Sound	12	4	58
Snooper	10/75	Equipment test	Catalina Island, Calif.	15	5	52

Table 6—Submersible Utilization Funding Sources, FY 1976

Submersible	Funding							
	Federal		Foundation		Academic		Private	
	Dives	Dive-days	Dives	Dive-days	Dives	Dive-days	Dives	Dive-days
Alvin	107	102						
Diaphus					35	20		
Johnson-Sea-Link I			139	91				
Johnson-Sea-Link II			129	81				
Mermaid II							17	7
Nekton Alpha							52	19
Nekton Beta	104	21					91	44
Nekton Gamma	90	38					67	31
PC-14C-2							39	37
Sea Explorer							3	2
Sea Ranger[2]								
Snooper							15	5
Star II[1]								
Total	301	161	268	172	35	20	284	145

[1] No input.
[2] Operational; no dives logged.

Table 7—U.S. Civilian Submersible Mission Categories, July 1975 to September 1976

Mission Category	Alvin	Diaphus	Johnson Sea-Link I	Johnson Sea-Link II	Mermaid II	Nekton Alpha	Nekton Beta	Nekton Gamma	PC-142-2	Sea Explorer	Sea Ranger [2]	Snooper	Star II [3]	Totals	Percentage of Total Dive Activities
Oil Industry [1]						41 16	49 24	10 4						100 44	11 9
Coral Harvest															
Test & Training	10 9		47 31	45 32		4 1						15 5		121 78	14 16
Inspection	20 20				12 4	4 2	49 24	48 19	39 37					172 106	19 21
Fisheries	7 7							31 13						38 20	4 4
Salvage	6 6					7 2	4 2	15 3						32 13	4 3
Biology	66 66	35 20	79 53	75 46			104 21	90 38						449 244	51 49
Geology	41 41	35 20	79 53	75 46			86 21	90 38						406 219	46 44
Pollution	10 10						26 5							36 15	4 3
Cable Bury															
Movie		13 7	9 7	5 3										27 17	3 3
Demonstration								2 1						2 1	0 0
Other [4]										3 2				3 2	0 0
Total Dives & Dive-Days Logged	107 102	35 20	139 91	129 81	17 7	52 19	195 65	157 69	39 37	3 2	0	15 5	?		

[1] Includes Pipeline Inspection and Route Surveys.
[2] Operational. No Dives Logged.
[3] No Information Obtainable.
[4] Recovery of Drowning Victim.

00 Dives (upper numbers)
00 Dive Days (lower numbers)

Table 8—Status of U.S. Habitats Technology Laboratories

Name	Owner	Operational depth (ft).	Status (as of June, 1976)
EDALHAB	University of New Hampshire	45	Inactive; last used in Project FLARE Fla., Jan-Apr. 1972. Located at Woods Hole, Mass.
HYDROLAB	Perry Foundation	50	Inactive; used in Bahama Banks Research Program during FY-73, 74, 75. Located offshore at Freeport, Bahamas.
TEKTITE	General Electric	80	Inactive; last used in 1970 TEKTITE I project in Virgin Islands. Donated to Franklin Institute at Philadelphia.
LA CHALUPA	Perry Oceanographics	100	Inactive; used FY-73, 74, 75. Located at Miami, Fla.
AEGIR	Makai Range	550	Inactive; last used in Hawaii in 1971 by the Navy Dockside testing in FY-74 by University of Hawaii. Located at Makai Range.
	Nonsaturation diving (university projects)		
PORTALAB	University of Rhode Island	30	Inactive; located at the University
LAKELAB	University of Michigan	30	Inactive; located in Lake Michigan.
UW-LAB	University of Wisconsin	30	Launched October 75 at Lake Mendota, Wisc.
SUNY LAB	State University of New York	30	Launched 1976 at Smithtown Bay, Long Island, N.Y.

MARINE SCIENCE APPLICATIONS

This section summarizes MUS&T-sponsored activities that deal with practical applications of scientific studies and missions, such as surveys of ocean dumping and dumpsites, deep-sea studies of fauna, surveys of lobster and fish eggs, and assessments of marine geologic features and processes. Summarized missions are mainly U.S. coastal zone endeavors conducted with submersibles. Other scientific missions are described under Interagency Activities and International Activities.

DEEPWATER SUBMERSIBLE ACTIVITIES, 1975

Four NOAA-sponsored projects describe submersible missions in deepwater—two at Deepwater Dumpsite 106 and two at Veatch Canyon. Several shallow-water (in less than 2,000 ft) submersible missions were supported by MUS&T, including several in which participation was joined by Environmental Protection Agency (EPA), U.S. Protection Agency (EPA), U.S. Geological Survey (USGS), and NOAA's Atlantic Oceanographic and Meteorological Laboratories (AOML) and National Marine Fisheries Service (NMFS). Missions by EPA and the USGS were only peripherally associated with NOAA/MUS&T and are listed without detailed descriptions; results of these missions are published by the agencies concerned. Shallow-water submersible missions in 1976 included four, under the auspices of the USGS, U.S. Army Corps of Engineers, and NOAA/AOML and NMFS.

Deepwater Dumpsite 106 Survey and Fisheries Studies

Dive Mission A

Note: This mission was a continuation of earlier DWD-106 *Alvin* surveys.

Date: July 23 to August 4, 1975 *Principal investigator:* Daniel Cohen, NMFS Systematics Laboratory, Smithsonian Institution, Washington, D.C.

Facilities used: Alvin and escort ship *Albatross IV*

Area of investigation: 90 miles due east of Cape Henlopen, Del.

Operations and Procedures

Five dives were made within the dumpsite limits; four were in areas to the west and northeast; and one was to a midwater depth of 1,086 m being sampled by the *Albatross IV.* Depths at the bottom locations ranged from 1,086 to 2,507 m.

Samples collected for analysis were: heavy metals analysis—8 tube cores; hydrocarbon analysis—9 tube cores; infauna—5 tube cores, 10 box cores; epifauna—coop net samples; water samples—17 samples; geology—2 sediment and 2 rock samples; and radioactivity—5 box cores, 11 tube cores.

Twenty-five transects were run along the bottom over a total distance of 9,528 m. Photographs and visual estimates were made of the kinds and numbers of fishes and larger benthic invertebrates.

Results

Findings are being studied, and a summary of the results is being prepared. Of the 10 dives, 3 were made in an abandoned radioactive dumping area where sealed and leaking drums of material were located.

Dive Mission B

Date: July 31, 1975

Location: Hudson Canyon

Purpose: To observe the swimming of abyssal fishes and obtain quantitative data that are comparable with information available on the swimming of shallow-water fishes.

Operations and Procedures

Swimming of *Antimora rostrata,* a locally abundant benthopelagic deep-sea gadiform fish of the family Moridae, was photographed during *Alvin* dive 589 (38°52'3"N, 72°17'1"W; 2,400 m; 2.7°C) near Hudson Canyon while the deep submersible was running a straight-line transect along a flat bottom. In this region the fish, *Antimora* occurs at depths about 1,000 to 2,700 m. Its greatest abundance is near 2,000 m.

Distance traveled over the ground was measured by means of an externally mounted odometer wheel connected with an internal counter. A photographic record was made with the externally mounted EG&G camera and stroboscopic system, set for one exposure every 10

Figure 10. *Antimora* swimming ahead of submersible *Alvin* at 2,400 m near Hudson Canyon. Note pectoral fine widely spread in horizontal plane. Sediment and invertebrates indicate the absence of currents.

seconds. Bottom current was negligible. Photographs showed fine bottom sediment marked with tracks, small mounds, and depressions; ripple marks were absent (fig. 10).

Results

An *Antimora* swam ahead of the submarine for 4.2 min over a distance of 99 m at a speed of 39.2 cm/s (= 0.88 mph = 0.76 kn). Direct determination of the fish's size was not possible as all photographs were tail-end views; however, in several exposures the pectoral fins are spread out and close to the bottom. By projecting negatives on a grid it was possible to determine the length of a pectoral fin (PL) and from this calculate a total length (TL) for the fish of 27 cm (an average of estimates from two different photographs; using the relationship PL = 0.162 TL derived from measurements on 14 examples of *Antimora* recently trawled from the U.S. east coast).

On the basis of the photographs at hand, *Antimora* fits best into the subcarangiform mode of swimming. Some other fishes swimming in this fashion are *Salmo, Carassius, Leuciscus,* and *Gadus*. The level of swimming speed fits best into the classification of "Prolonged (activity level maintained between 200 min and 15 s)."* This particular *Antimora* may have been swimming at near maximum prolonged speed for its size, as the submersible slowly but steadily gained ground on the fish during the photographic sequence; the fish eventually turned aside from the submersible's path. The swimming speed of *Antimora* in lengths per second is 1.45, which agrees well with a 1 to 3 lengths figure for endurance swimming of shallow-water gadoids.

A Reynolds number of 6.3 x 10_4 was calculated using hydrographic data for the area given by Warsh (1975). It is within commonly observed limits (Webb 1975).

Respiration of a benthopelagic gadiform fish (*Coryphaenoides acrolepis*) at 1,230 m and of a benthic community at 1,850 m, both measured in situ, proceed at rates 2 orders of magnitude lower than in lesser depths. If *Antimora,* also a gadiform although of a different family, respires at a rate like that of *Coryphaenoides,* while generating power at the same rate as a shallow-water fish, then perhaps it performs more efficiently. Such an interpretation is consistent with the findings of other scientists who have studied several enzyme systems in *Antimora* and found them well adapted to the extremes of temperature and pressure at which this fish lives. Another possibility is that *Antimora* can incur a larger oxygen debt than can *Salmo* (table 9).

Table 9.—Characteristics of two fishes swimming in the subcarangiform mode, the abyssal Antimora rostrata and the shallow-water Salmo gairdneri

Characteristics	*Antimora*	*Salmo*[1]
Length cm	*27*	28.2
Swimming speed cm/s	*39.2*	39.6
Body length/s	*1.45*	1.40
Swimming power erg/s	3.6 x 10^5	3.76 x 10^5

[1]Data from Webb (1975).

Veatch Canyon Benthic Oceanographic, Geologic, and Ecological Surveys

Date: June 24-30, 1975

Principal investigators: Joseph Uzmann and Richard Cooper, National Marine Fisheries Service, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Equipment and facilities: Research submersible *Alvin* and support vessel *Lulu.*

Purpose: To investigate and document the ecological and geological features of deeper regions of the Veatch Canyon, giving special attention to sediment processes, near-bottom dynamics, and the role of benthic crustacea and fishes in bioturbation and habitat utilization. The distribution, behavior, and ecology of the red crab, *Geryon quinquedens,* the lobster, *Homarus americanus,* and the Jonah crab, *Cancer borealis,* were studied.

Description

Dives were planned to traverse a specifically directed upslope track of 1.6 nmi over the bottom at a speed of

*Described by Webb P.W. 1975. Hydrodynamics and energetics of fish propulsion, *Bull. Fish. Res. Bd. Canada,* 190, i-x+1-158.

about 0.3 kn. At greater speeds, apparent relative motion precludes careful assessment of details and does not permit sufficient leadtime for effective photography or video pictures. Four dives were completed without significant technical problems. Each dive was completed within 6 to 7 hours. This time was adequate for stopping, bottom sitting, or close maneuvering about a site to measure bottom currents, obtain core samples, and carefully compose still photography and video documentation.

Three joint geology-biology dives (576, 578, and 579 along transects 1, 2, and 3, respectively) and one biology dive (577 along transect 6) were completed in the upper portion (1,255-200 m) of the canyon (fig. 11). Dive transect 6 was made in part to recover a test bed of materials emplaced during the 1974 dives by the submersible *Nekton Beta.*

Results

The test bed of previously emplaced materials could not be located despite careful search at and about the original drop site. It was concluded that it had been removed from its original location by trawler, line-trawl, or pot-trawl activities, which are common in the area. A replicate package emplaced slightly deeper in the same vicinity in 1974 was trawled up and reported 4 days after its emplacement.

The canyon is incised in semiconsolidated clayey silt, probably of Pleistocene age. A thin (few centimeters) layer of silt and clayey silt covers most of the canyon floor. The semiconsolidated clayey sediments provide a stable substratum that is worked into burrows, tunnels, grottos, and craterlike excavations by a variety of bottom dwelling fishes, crustacea, and annelids. Based on color and odor, the sediments have a high organic content and are generally homogeneous within the first 20 cm—probably the result of the high concentration of organisms in and on the bottom. The area is a prime example of sediment alteration and, to some degree, of sediment transport by biological activity.

Currents were slight (8 cm/s) during the dives, but it is apparent from ripple marks and scour around large rocks that strong currents prevail in the canyon from time to time. The predominating flow direction as discerned from ripple marks was down-canyon.

Temperatures ranged from 10.5°C at 200 m to 3.9° at 1,000 m and changed little thereafter to the maximum depth (1,255 m) of the dive series.

Red crabs were observed during all dives, from the maximum depth of 1,255 m to as shoal as 348 m. Calculated abundance overall as determined from video tapes, audio tapes, and interim abundance estimates was 100 to 200 crabs per hectare (40-80/acre). The majority (60%) of crabs seen and counted were relatively deep (800-1,300 m). They decreased in abundance from 800 m to the 300-m level of extinction. Similarly, the majority (70%) of coupled (mating) pairs observed were also in the deeper half of the depth range. The ratio of single crabs to mating pairs was 10:1 in the deeper range and 15:1 in the shoaler range.

Jonah crabs were observed on three of the four dives (transects 2, 3, and 6), but only within the shoaler (500-m) levels of the study. Density increased gradually from 450 to 200 m, the shoalest level traversed. Calculated density overall was 1.1 to 2.2 crabs per hectare. The distribution of Jonah crabs overlapped that of red crabs only within the 300- to 500-m interval within which neither species is particularly abundant because the Jonah crab is at its lower level of distribution and the red crab at its upper level. Within this range, however, red crabs enjoyed an abundance ratio of 3:1 over Jonah crabs. The nominal overlap of the two species implies little overall competition, but with some advantage to red crabs within the overlap.

Lobsters were observed on three of the four dives (transects 2, 3, and 6) in the same depth range and circumstances as described above for Jonah crabs. A single large male weighing 18 pounds was captured without harm with the manipulator arm of *Alvin* at 264 m; this exceptional specimen remains on display in the NMFS Aquarium at Woods Hole, Mass. Estimated density of lobsters as determined from direct counts was approximately equal to the Jonah crab estimates, thus giving a calculated density of 1.1 to 2.2 lobsters per hectare and a 1:1 ratio with Jonah crabs. Within the area of overlap with red crabs (300-500 m), lobsters were outnumbered 3:1; thus, in terms of interspecific competition between the three species, the ratios were 3:1:1.

Observations also were recorded on some 30 other species of fishes and invertebrates that are part of the canyon ecology.

DEEPWATER SUBMERSIBLE ACTIVITIES, 1976

Veatch Canyon Megabenthic Survey

Date: July 7-15, 1976

Principal investigators: Joseph Uzmann and Richard Cooper, National Marine Fisheries Service, and Woods Hole Oceanographic Institution, Woods Hole, Mass.

Equipment and facilities: NOAA MUS&T charter vessels RV *Lulu* and research submersible *Alvin*

Description

The support vessel *Lulu* and submersible *Alvin* (operating out of Woods Hole, Mass.) completed a series of eight dive transects at Veatch Canyon to observe directly the biology and geology of the canyon axis and slopes.

Results

Six joint biology/geology dives (667, 668, 669, 670, 671, 672), one short pilot training dive (673), and a final dive with wholly biological objectives (674) were completed within the mission period. Significant findings on

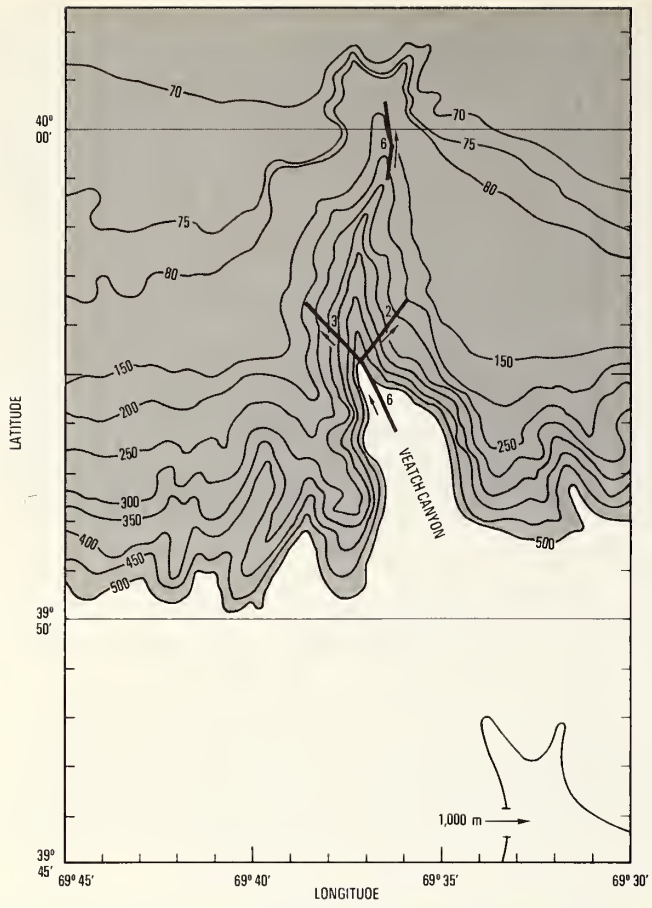


Figure 11.—Transects completed by submersible *Alvin* in Veatch Canyon, June 24-30, 1975.

qualitative, quantitative, and behavioral characteristics of canyon and slope fauna were documented on audio and video tapes and with still-camera equipment. These dives effectively completed a 4-year study of the biology and geology of Veatch Canyon and six other submarine canyons located eastward along the continental shelf margin. Data and findings from this cruise will be used with those from other NOAA MUS&T-sponsored submersible operations (*Nekton Beta* and *Alvin* dives by NMFS, Woods Hole) to provide comprehensive baseline data of the biology, ecology, and geology of biologically important regions of the New England outer continental shelf and slope.

Deepwater Dumpsite 106 Assessment

Date: June 22-30, 1976

Principal investigator: Gilbert T. Rowe, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Equipment and facilities: Submersible *Alvin,* support ship *Lulu,* and escort vessel *Dallas;* 1 sediment trap array (3 traps), 1 elevator with 2 grab respirometers and a time-lapse camera, and 3 elevators with time-lapse cameras.

Location: Off Governors Island, N.Y.

Purpose: General: To study the fate and effects of liquid toxic waste disposal at Deepwater Dumpsite 106 (DWD 106).

Bottom dives:

1. To characterize bottom and biota at sea floor in region of presumed impact.
2. To conduct suite of observations and experiments on sediment, current, and biological interactions to estimate rates of deposition and erosion.

Midwater dives:

1. To characterize composition and relative abundance of midwater organisms capable of interacting with plume of wastes.
2. To capture midwater organisms (using newly developed slurp gun) for physiological and taxonomic studies.

Free vehicle deployments of time-lapse cameras: To estimate rates of erosion and biological reworking of surface sediments.

Neuston sampling from Lulu: To determine characteristics of assemblages of midwater organisms ascending to surface (into plume) at night.

Description

Studies of the nocturnal neustonic and mesopelagic fishes were undertaken at DWD 106 in an effort to reveal possible long-term or chronic effects of the dumping. The hypothesis was that no matter how the toxic wastes were distributed in the water column these small fishes would encounter them at some time during their 500- to 1,000-m daily vertical migrations. If the fishes were affected by the wastes, and in general they seem to be quite delicate, chronic exposure should reduce or eliminate these populations at DWD 106.

Targets of the investigation were the myctophid *Gonichthys coccoi,* normally the dominant member of the nighttime neuston in Slope Water, and the characteristic midwater scattering layer (DSL) known as "Alexander's Acres." This DSL, found in the Slope Water and nowhere else, is composed of huge aggregations of the myctophid *Geratoscopelus maderensis.* Twenty neuston tows were made from *Lulu* with a 1-m neuston net (4-mm mesh).

Results

All observations indicated that the populations in the DWD 106 site were quite sparse. Six neuston tows from *Lulu* on the night of June 23 (the day of a dump) caught one *Gonichthys;* four tows on June 24 caught none; five tows on June 26 (3 days after a dump) caught six; five tows June 27 (the day of a dump) caught one. Expectations, based on Slope Water collections made elsewhere in other years, were that 30 to 50 *Gonichthys* should have been caught each night. Echo-sounding from 1600 on June 27 to 0900 June 28 showed a DSL to be present

between 200 and 400 fm, although "Alexander's Acres" did not appear to be a part of it. At night, little migration above 200 fm was observed. No "Acres" were seen on the sonar used from *Alvin* on the June 29 dive. This feature appears, from past experience, almost ubiquitous in the Slope Water, yet it was apparently absent at DWD 106.

SHALLOW-WATER SUBMERSIBLE ACTIVITIES—1975

EPA Assessment of Dumpsites

Date: August 17-21, 1975
Location: Baltimore Trough, middle continental shelf
Purpose: Assess biologic, geologic, hydrologic characteristics of the Philadelphia sewage and DuPont acid dumpsites; selective sampling of bottom sediments and organisms; measurement of bottom currents and water-column data. Assist in the assessment of waste impact on geologic phenomena and evaluate the character of the bottom with respect to microtopography, sediment texture, and mobility.
Sponsor: EPA
Participants: EPA, USGS, Coast Guard, and University of Delaware
Facility used: Submersible *Nekton Beta*
Number of dives: 26
Number of dive days: 5
Depth: 60 to 80 m

USGS Environmental Assessment of Baltimore Trough

Date: August 22-26, 1975
Location: Baltimore Trough, middle continental shelf
Purpose: Direct observations of geologic, biologic, and hydrologic conditions in an area of potential oil exploration. Of primary concern are the magnitude, distribution, and character of ripple marks.
Sponsor: USGS
Participants: USGS, EPA, Virginia Institute of Marine Science (VIMS), and commercial firm
Facility used: Submersible *Nekton Beta*
Number of dives: 20
Number of dive days: 4
Depth: 59 to 79 m

NOAA/AOML Investigation of New York Bight and Hudson Shelf Valley and Canyon

Date: August 27 to September 3, 1975
Location: New York Bight, Hudson Shelf Valley, and Hudson Canyon
Purpose: Geological and biological environmental assessment
Sponsor: NOAA/MUS&T
Participants: NOAA/AOML and NMFS, and Adelphi University
Point-of-contact: George Freeland, NOAA/AOML
Facility used: Submersible *Nekton Beta*
Number of dives: 11
Number of dive days: 3
Depth: Maximum 305 m

NOAA/NMFS Ecological Investigation Off Jeffreys Ledge

Date: September 5-11, 1975
Location: Jeffreys Ledge, Gulf of Maine
Purpose: Provide a descriptive ecology of offshore, deepwater benthic algae in the temperate western North Atlantic Ocean. Effect a systematic survey of the topography, bathymetry, and benthic community beyond the defined perimeter of the *HELGOLAND* site; document the nature and variability of the bottom community beyond the range of the resident divers; and make orientation dives for NMFS Northeast Fisheries Center (NEFC) biologists. This experiment is part of Project FISSHH, reported under International Activities.
Investigators: James R. Sears, Southeastern Massachusetts University, North Dartmouth, Mass., and Richard A. Cooper, NOAA National Marine Fisheries Service, Woods Hole, Mass.; *Associate investigator:* Robert Steneck, Department of Botany, University of Maine.
Facilities and equipment: Submersible *Nekton Beta,* RV *Advance* support ship, and scuba diving

Description

Studies of benthic algal communities in coastal waters off northeastern North America have provided information on the composition and habitat ecology of inshore algal populations along temperate and subtropical shorelines. However, in deep offshore habitats, algal communities are less well known. The deepwater populations have been described for reefs off North Carolina and the west coast of Florida where waters are warm and the major floristic affinities are clearly subtropical in character. In the temperate to boreal regions of the western North Atlantic, where cool waters affect offshore benthic algae, there have been few direct observations of their distribution, composition, and habitat ecology.

During September, October, and November 1975, offshore algal communities were studied at two locations on Jeffreys Ledge in the Gulf of Maine, 18 to 37 km seaward from the nearest shoreline. This study was part of international Project FISSHH, an undersea research program on ecological factors affecting survival of North Atlantic herring (*Clupea harengus harengus*) during their spawning and early life history phase. Herring deposit their eggs over rock, gravel, and coarse sand substrata that are occupied by sparse to dense populations of benthic algae. The benthic algae provide an important attachment substratum for the eggs of the herring and can affect posthatching mortality.

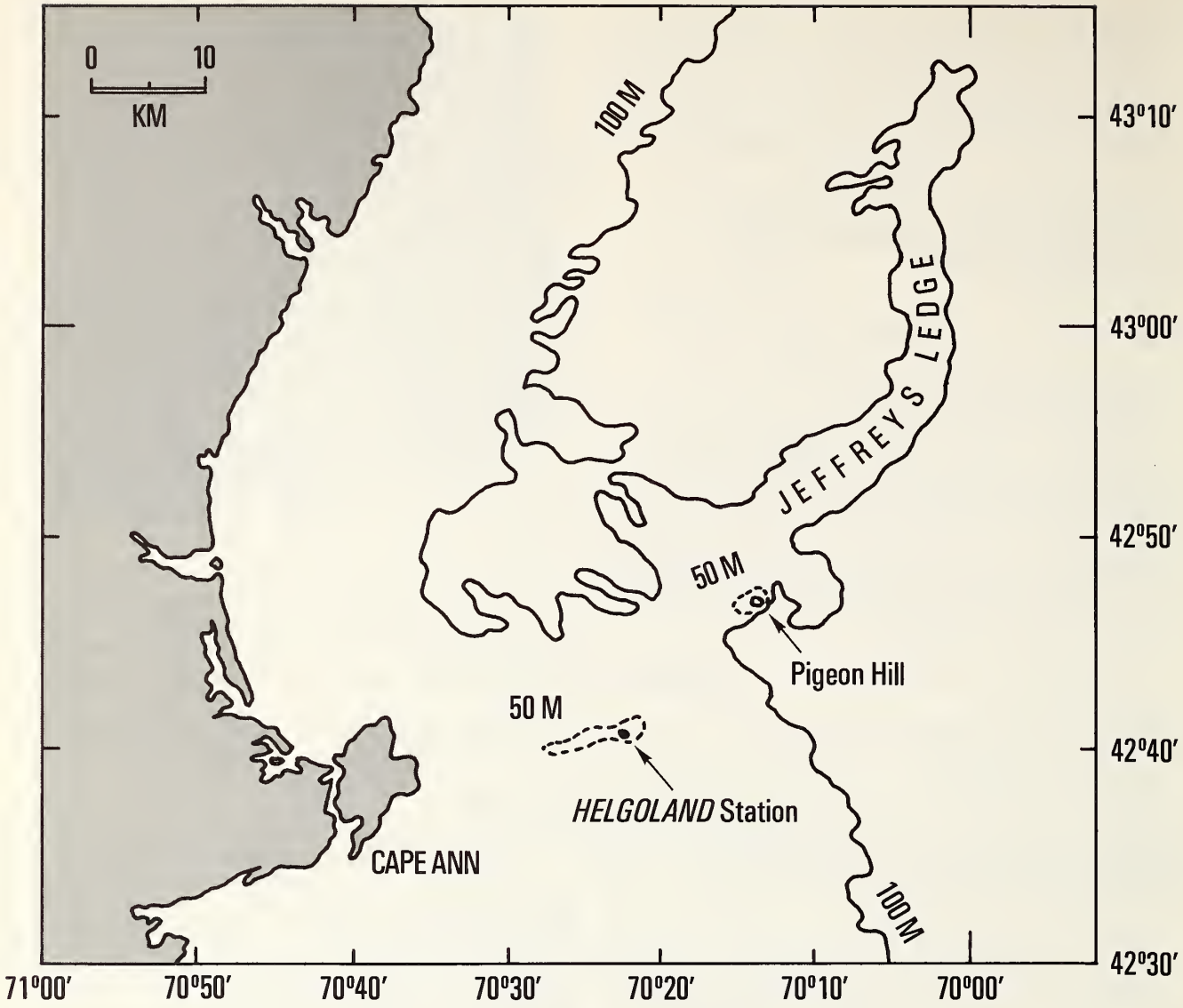


Figure 12.—Jeffreys Ledge; Pigeon Hill and *HELGOLAND* Staions.

Collections and observations were made first near the *HELGOLAND* Underwater Laboratory, located at an historical herring spawning site. This site, designated the "Habitat Station," 18 km east of Rockport, Mass. (42°41'0"N, 70°24'2"W). In-situ collections were made near the top of the knoll at water depths of 30 to 39 m and within a 200-m radius of Habitat Station. Additional collections and observations were made along a line transect about 1 km long leading from *HELGOLAND* to the southeast and to a depth of 48 m, 3 to 4 m deeper than the lowest limit of macroscopic benthic vegetation.

The sea floor at Habitat Station has scattered boulders and stones resting in a sandy-silt matrix on a gently rolling terrain of hills and depressions. Rocks and boulders to 2-m diameter were swept free of most silt and sediment by daily currents having speeds up to 0.1 knot. These NW-SE currents changed direction by 180° about every 6 hours. Bottom waters at 30 to 48 m had an average temperature of 7.0°C during September, and 9.5°C following the breakup of the thermocline in early November. The annual bottom-water temperature range for the site is 6.5°C, from about 4.0° to 10.5°C.

A second truly oceanic station was 37 km offshore at Pigeon Hill (42°46'5"N, 70°14'5"W) near the south central portion of Jeffreys Ledge (fig. 12). The top of Pigeon Hill is 29 m deep. The knoll is about 1 km in diameter at the 75-m depth contour, 4 km in diameter at depths of 100 to 125 m. A granite outcrop in the form of a sloping shelf forms the top of the knoll and is kept free of silt by daily tidal currents. Loose stones and boulders (a characteristic at the Habitat Station) were not seen near the top of the knoll. Collections and observations were made at depths of 29 to 35 m during two scuba dives on November 18, 1975. Bottom temperatures and currents were similar to those measured at Habitat Station.

Two submarine dives and six scuba dives were made on Jeffreys Ledge during September and November 1975. The two-person research submersible *Nekton Beta* was used for two 30- to 45-min dives to a depth of 49 m to determine the extinction depth of the benthic algae. The small size and maneuverability of this submersible permitted detailed visual observations to within 0.25 m of the bottom, and made it possible to identify plants and to estimate algal density as a percentage of the vegetation-covered substratum. Limited in-situ collections of the substrata and attached algae were made, using an external mechanical arm and catch bag.

During the six scuba dives, additional collections and observations were made at depths of 29 to 39 m. Extensive algal samples, and rocks with attached algae (crustose forms) were collected in nylon mesh bags or were placed in wire baskets and retrieved by line from the surface. About 100 algal-bearing stones and rocks were collected in this manner; the algae identified in their living condition. Voucher specimens are in the herbarium of Southeastern Massachusetts University.

Results

The benthic algae of the offshore, deepwater, sublittoral community at 29 to 45 m Jeffreys Ledge were represented by at least 20 species. Of these 20 species, 17 taxa belonged to the Rhodophyta and were responsible for the uniformly red character of this deep-growing offshore benthic vegetation. Also included were two small and infrequently encountered members of the Chlorophyta and one coccoid member of the Cyanophyta. The brown algae, which are characteristic of shallower inshore algal associations, were conspicuously absent.

Two benthic algal associations characterized the deepwater sublittoral vegetation at Jeffreys Ledge. Fleshy, macroscopic red algae dominated the rocky substratum from 29 to 37 m. Encrusting coralline algae formed an association from 38 m to the extinction depth (lower limit of vegetation) of multicellular algae at 44.5 m.

At depths from 29 to 36 m, bushy stands of *Ptilota serrata* covered 5 to 100 percent of the available rocky substratum. These dense stands were 10 to 20 cm thick and accounted for a least 95 percent of the algal biomass. Because of the abundance, uniform distribution, and clear dominance by one species, the *Ptilota* Association is recognized. Several additional red algae occurred as minor associates of the *Ptilota* Association and are listed in table 1 in order of their decreasing abundance. *Phyllophora* and *Phycodrys* were the most conspicuous. They were present with a frequency of about one plant/25 m, each clump being 5 to 10 cm high. Other red algae grew as epiphytes on *Ptilota* or as fleshy crusts on stones. Many red crusts bore reproductive structures and provided excellent material for determining the systematics and biology of this poorly understood element of the deep sublittoral vegetation.

The deepest association observed on Jeffreys Ledge was the *Lithothamnium* Association, which was characterized by encrusting coralline forms. Based largely on observations made during submersible dives, these encrusting calcified algae extended to greater depths than the *Ptilota* Association and dominated the vegetation below 37 m. At depths of 39.5 to 42.5 m, encrusting corallines were the only macroscopic algae seen. They covered from 10 to 75 percent of the available rocky substratum. Below 42.5 m these crusts decreased markedly in abundance and were sparsely distributed. The greatest depth at which they occurred was 44 to 45 m, where they formed the lowest limit of multicellular algae observed at Jeffreys Ledge.

Cape Cod is an effective biogeographic barrier to many marine plants and animals. To its immediate south, near Martha's Vineyard, fleshy algae at the extinction depth (20 to 22 m) were represented by species (*Phycodrys* and *Phyllophora truncata f. brodiaei*)different from those at Jeffreys Ledge. *Ptilota* does not commonly occur south of Cape Cod. Such variations of species composition in the deep sublittoral at different inshore and offshore geographic regions support the view that the sublittoral vegetation forms multiple associations rather than tripartitely zoned benthic communities as advanced by others. (See discussion of sublittoral algal zonation by Sears and Wilce 1975.)

One green alga and possibly several species of yet undescribed fleshy red crustose algae were collected for the first time in eastern North America at Jeffreys Ledge. *Uronema curvata* was commonly seen on fleshy red crusts and stones and is newly reported here for the western North Atlantic. Its occurrence, together with the single specimen of *Derbesia,* indicate that green algae may occur with the red algae in the deep sublittoral in the western North Atlantic, at least in the clear waters over the offshore continental shelf. *Derbesia* had been reported from deep water both to the north and to the south of Jeffreys Ledge. The pigments siphonoxanthin and siphonein are major carotenoids in *Derbesia* and other siphonalean green algae; their absorption spectra are similar to that of fucoxanthin and thus they absorb further into the green region of the light spectrum than carotenoids of most other green algae.

The presence of extensive diatom populations living endozoically among the tissues of sponges at 47 m, a depth greater than the extinction depth of free-living

algae, suggests either a more efficient use of light than that of other algae or a possible heterotrophic source for part of their nutrition. This is the first report of endozoic diatoms from deep water; a clarification of their nutritional status must await further study.

The seasonal stability, together with clear extinction depths of foliose and encrusting algae of the continental shelf, may offer a valuable bioindicator of water clarity and marine environmental perturbations. Using the extinction depth of algal associations as a natural bioassay of oceanic light penetration has certain advantages over monitoring water clarity by instruments. The most obvious advantage is that algae reflect an integration of year-round light conditions. Their extinction depth is in part determined by the amount of light they have received, and as perennials they are not subject to rapid changes due to short-term light changes from cloud cover, wind effects on surface water, or seasonal fluctuations of light intensity. Short-term light measurements or experimental determinations of photosynthesis and respiration are strongly affected by these factors. Also, offshore algal populations reflect water clarity more than inshore populations where the sediment load in the water is higher and where the absence of silt-free substrata may limit algal growth (Lamb and Zimmerman 1964).

USGS Environmental Assessment of Georges Bank

Date: September 12-16, 1975
Location: Georges Bank
Purpose: Direct observations of geologic, hydrologic, and biologic phenomena. Of primary concern are: the magnitude, distribution, and character of ripple marks; measurement of bottom currents; and distribution patterns and habitats of benthic and epibenthic fauna.
Sponsor: USGS
Participants: USGS and WHOI
Facility used: Submersible *Nekton Beta*
Number of dives: 9
Number of dive days: 3
Depth: 80 m

SHALLOW-WATER SUMERSIBLE ACTIVITIES, 1976

NOAA/NMFS Fisheries Study in Gulf of Maine

Date: June 15-29, 1976
Location: Southwest quadrant, Gulf of Maine
Purpose: Observe and record number, size, composition, behavior, and spatial distribution of fish and invertebrates.
Sponsor: NOAA/MUS&T
Participants: NOAA/NMFS and WHOI
Facility used: Submersible *Nekton Gamma*
Number of dives: 31
Number of dive days: 13
Depth: 18 to 207 m

USGS Evaluation of Changes in Georges Bank Region

Date: July 1-7, 1976
Location: Georges Bank region
Purpose: Evaluate changes in bottom configuration and biology of area surveyed in 1975.
Sponsor: USGS
Participants: USGS, VIMS, and private consultants
Facility used: Submersible *Nekton Gamma*
Number of dives: 8
Number of dive days: 5
Depth: 77 to 85 m

USGS Study Off Atlantic City

Date: July 9-14, 1976
Location: 60 miles east of Atlantic City, N.J.
Purpose: Biological and geological research.
Sponsor: USGS
Participants: USGS and others
Facility used: Submersible *Nekton Gamma*
Number of dives: 7
Number of dive days: 6
Depth: 80 m estimated

COE Ocean Dredge Material Disposal Site Survey

Date: July 15-20, 1976
Location: Rhode Island Sound
Purpose: Environmental assessment of site for disposal of dredge material.
Principal investigator: Gilbert L. Chase, U.S. Army Corps of Engineers
Participants: COE, NOAA/NMFS, and USGS
Facilities used: Submersible *Nekton Gamma* and RV *Atlantic Twin*
Number of dives: 23
Number of dive days: 5
Depth: 27 to 63 m

Description and Objectives

The survey was undertaken as part of a study to develop an environmentally acceptable management program for disposal of dredge material in the Rhode Island and southern Massachusetts region. Principal survey areas where the natural depression or basin (defined by the 120-ft depth contour) that transverses Rhode Island Sound in an east-west direction and the Browns Ledge site proposed for disposal of dredge material. Major objectives were to determine the distribution and relative abundance of fish and other macrobenthic animals; delimit any biologically critical

areas, such as breeding and spawning grounds or unique habitat; confirm the nature of bottom substrate and currents; and determine more precisely the depositional or containment suitability of the proposed Browns Ledge disposal site.

Direct visual observations of the sea floor were made using the two-person research submersible *Nekton Gamma*. All dives were made during daylight between 0600 and 1800 hours. Navigational positioning for the dive stations was by loran A. The submersible's position was tracked and plotted from radar ranges and relative bearing to the station buoy. At the Browns Ledge study site a permanent navigation buoy facilitated the on-going sampling program and precluded the use of another buoy for dives performed within the immediate vicinity. Before submerging, the submersible would line up with the support ship to obtain the desired directional bearings for transit. On the bottom, it would travel a predetermined magnetic compass course. A floating tether ball and line attached to the submersible provided a continuous visual means of tracking from the RV *Atlantic Twin*.

Equipment included an in-situ thermister probe and depth recorder with internal readouts. Current measurements were obtained with a Savonius current meter mounted on the bow plane. Extensive photographic documentation of the substrate and associated benthic communities was performed.

Results

A total of 23 dives were completed at depths ranging from 27 to 63.4 m (88 to 208 ft). Dive station locations and direction of transit are shown in figure 13. Bottom temperatures varied from 8.7 to 12.8°C (47.6 to 55°F). Currents were absent or, where detectable, very weak (0.1° to 0.2 knot) and generally flowed southeast or northwest. Bottom visibility was reduced throughout the survey area by high concentrations of zooplankton and suspended organic matter in the water column, which interfered with photographic efforts. Suspended sediments were not observed.

Bottom sediments in the depression consist primarily of soft sandy muds or silt-clay muds. The topography is flat and monotonous. There is evidence of considerable biological activity in the form of burrow holes, tubes, mounds, excavations, tracks, and trails. The number of burrow holes and tubes suggested a very productive infaunal benthic community, but accurate estimates of numbers and biomass can be obtained only with conventional grab sampling gear.

Pleistocene glacial rock-boulder outcrops were observed on dive 22 and portions of dive 1 and 2 at the Browns Ledge site. Boulders also were observed on dive 16 along the western moraine margin. Gravelly sand sediments were dominant at dive station 9. Rippled sands, probably postglacial Holocene deposits, were present over a portion of the bottom transversed at station 3 but progressing eastward changed rapidly to muds. The dives in the eastern part of the depression, and the deeper trough in the west (dives 5 to 8), suggested that deposition is taking place.

Some important observations resulting from the survey are:

1. In addition to the Browns Ledge dives, sand waves were observed at stations 3, 9, 14, and 15. These wave structures or undulations varied in amplitude from 30 to 46 cm (12 to 18 in.). Wavelengths attained 2 m (6 ft). Orientation of the wave crests, 090° to 060°, suggests storm movement from the southeast.

2. Two dives were carried out within the proposed Browns Ledge disposal site. Bottom sediments at the center of the site marked by Research Buoy (dive 1) are silty sand. The topography is featureless with the exception of a few small depressions. Live quahogs, *Arctica,* several cancer crabs, and numerous small red hake, *Urophycis chuss,* and *Asterias vulgaris* starfish were recorded in association with this sediment type. Within 107 to 198 m (350 to 600 ft) of the center buoy and proceeding southward the substrate changed to rocks and scattered boulders. Small ripples 10 to 12 cm (3 to 4 in.) in amplitude and approximately 30 cm in length were observed in some areas. Large sand waves 0.9 to 1.2 m (3 to 4 ft) characterized the bottom at other locations. A film of silt covered the boulders and rock. The second dive, diagonally across the mile-square site, showed a rather sharp transition in the substrate from rocks and boulders in the west to sandy muds in the southeast. The softer sediment showed signs of much biological modification. Ripple marks and sand waves were confined to the western portion of the dive. Unlike the first dive, there were no crabs or quahogs seen and only a couple of hake. Cunner, *Tautoglabrus adspersus,* a small-size fish species, dominated the fish fauna, but its distribution was restricted to the rocky areas. Visibility was extremely poor, 5 to 6 ft maximum, throughout both dives.

3. Death assemblages of adult ocean quahogs, *Arctica islandica* (size 6 to 10 cm), were found at stations 1 and 21. The shell patches each covered an estimated 6-m^2 area. Many of the valves or clappers were in and upright position, hinges were still intact with little silt accumulation inside, indicating recent death. Cause of the die-off is unknown but could be overpopulation, disease, predation, or some physical-chemical synergistic effect. A mass aggregation of starfish, *Asterias vulgaris,* was seen and photographed in association with the quahog shells at station 1.

4. Numerous skeletal casts and breeding adults of the *Cancer borealis* were observed at stations 5, 6, 7, and 11. Significant numbers of cancer crabs also were recorded at dive station 4. This particular species and the smaller stone crab,

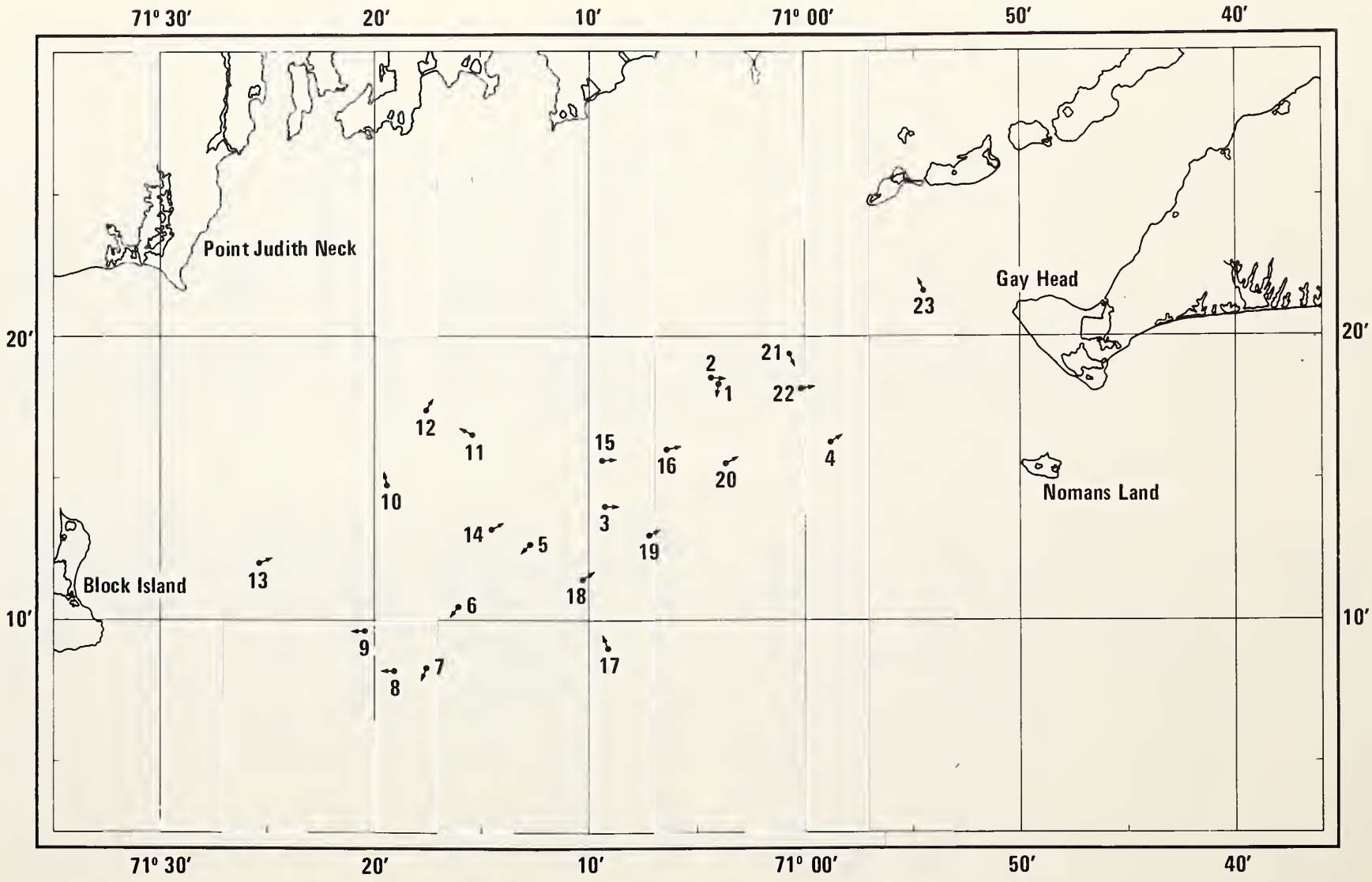


Figure 13.—Submersible *Nekton Gamma* dive stations in Rhode Island Sound, July 15-20, 1976. (Source: New England Division, U.S. Army Corps of Engineers)

Cancer irroratus, are responsible for much of the sea-floor biological perturbations.

5. Numerous red hake, *Urophycis chuss,* were observed living in shallow caverns in the flat bottom. This distribution and abundance of this species coincided with the cancer crabs. It is believed that the crabs initially construct the burrow or cavern inhabited by the hake. Also, newly molted crabs might serve as a source of food.
6. A small reddish-colored shrimp, possibly *Dichelopandalus leptocerus,* mysid shrimp, and Caprellids (a species of amphipod crustacean) were widely distributed over the survey area in relation to fine-grained sediments.
7. Chaetognaths dominated the zooplankton and were extremely abundant from the surface to the bottom.
8. Dense matlike carpets of amphipod tubes, either *Ampelisca* sp. or *Erichthonius rubricornis,* or both, characterized the bottom at station 23. Similarly, the sea floor observed on dive 21 east of the Browns Ledge study site contained conspicuous clusters or clumps of small tubes (probably a Sabellid worm or amphipod) at the sediment surface. Also occurring at these two locations was a large population ($50+/m^2$) of unidentified small crabs, 3 to 6 mm carapace width. The presence of these crabs may represent a recent hatch of *Cancer* sp. or merely a large concentration of a smaller species.
9. Only seven lobsters were sighted during the survey. There were no indications (i.e., molts) that any mass spawning or breeding had occurred in the area. Two lobster pot trawls were passed in transit from station 10 to station 11. Several pot trawl lines and individual pot buoys were noted in the vicinity of the Martha's Vineyard "Whistle" Buoy. Potting activity was observed in the immediate area of dive 22 where the rocky bottom is an ideal habitat for lobsters, but not a single sighting was made.
10. Live ocean quahogs, *Arctica islandica,* were sighted on various dives (stations 1, 11, 13, 17, 19, and 20), including the proposed Browns Ledge site. However, true population densities cannot be estimated. At present there appears to be little or no commercial fishing activity for this species within the surveyed area.

NOAA/AOML Investigation of New York Bight and Hudson Shelf Valley and Canyon

Date: July 20-31, 1976

Location: New York Bight Apex, Hudson Shelf Valley, and Hudson Canyon

Purpose: Examine the transition in sediments between the edge of the Continental Shelf and axis of the Hudson Canyon and Hudson Shelf Valley.

Investigators: George L. Freeland, Chief Scientist, NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, Fla., and Daniel J. Stanley and Andres Muldonado, Smithsonian Institution, Washington, D.C.

Facilities used: Submersible *Nekton Gamma* and RV *Atlantic Twin*

Number of dives: 19

Number of dive days: 9

Depth: 305 m maximum

Description

This cruise was part of a 42-day multiagency survey program (ending August 1, 1976) to examine the head of the Hudson Canyon, selected sites in the Hudson Shelf Valley, and the sewage sludge dumpsite in the New York Bight Apex. Objectives were to examine the transition in sediments from the edge of the Continental Shelf to the axis of the canyon and shelf valley.

Results

The cruise consisted of 2 days loading and in-transit, 1 day waiting for suitable diving weather, and 9 days of diving operations—including 10 dives in the Hudson Canyon, 8 dives in the Hudson Shelf Valley, and 1 dive at the sewage sludge dumpsite in the Bight Apex. In the head of the Hudson Canyon, a bottom sediment changed from gravelly sand to sandy mud in a seaward direction. Slopes of up to 15 were observed. No rock outcrops were seen, but zones of angular clay pebbles were apparent in several dives. In the Hudson Shelf Valley, slopes were less steep, but zones of clay pebbles were still present. Approaching the Bight Apex, the dive in the sewage sludge dumpsite had to be terminated because suspended matter increased so much that the bottom was no longer visible through about 0.1 m of water.

Interagency Activities

INTRODUCTION

The MUS&T Office has continued to cooperate with Federal agencies that have interests in underwater activities. As noted in the December 1972 report on "Manned Undersea Activities of the Federal Agencies and Utilization of Manned Undersea Research Submersibles and Habitats," the Interagency Committee on Marine Science and Engineering (ICMSE) has established a coordinating mechanism within NOAA's MUS&T Office for civil Federal agency programs to:

—Coordinate the use of national undersea platforms (present and future) to realize economics of operations and applications and provide continuity of support.

—Identify the need for these platforms and provide support for improvements in platforms as required in support of projects.

—Assist Federal agencies in planning the use of platforms and gaining access to platforms.

—Provide for replacement of platforms and new technological capabilities when needed for programs.

ICMSE also requested that the lead agency make platform data available to current and potential users, explore platform uses with other agencies, continue the accumulation of requirements and utilization data, defer new systems development until existing platforms are fully utilized or declared technically unsuitable, and transfer technology to the civil sector whenever possible.

During the FY-1976 report period a second summary on submersibles and habitats (1972-74) was presented at the 22d meeting of ICMSE on July 31, 1975. The Committee requested that NOAA continue to assess the Federal civil agency needs for submersibles and habitats and coordinate the use of available commercial and Navy assets. Industrial use of submersibles and their future availability to industry and the Federal civil agencies will also be examined.

The Committee also requested that NOAA study the desirability and feasibility of a cooperative Federal sponsorship of a shallow-water research submersible system, similar to the arrangements made for the deep-diving *Alvin*.

In view of the expected future increases in submersible usage (especially in offshore oil) and the three fatal submersible accidents, which resulted in five deaths within the last 4 years, the Committee also considered the desirability of a submersible safety seminar or study. (The last seminar was held in September 1972 at the Harbor Branch Foundation, Fort Pierce, Fla.) The scope of the seminar or study would include review and definition of safety problems experienced by operators and users, comparison of proposed solutions for compatibility with U.S. and foreign submersibles, and evaluation, conclusions, and recommendations for the most effective solutions.

Activities during the FY-1976 period are reported herein, including a third survey of the use of manned undersea facilities and the status of submersible safety studies. Details are provided below.

In addition to cooperative dive programs, MUS&T worked with ERDA, USGS, and NASA on further development of sea-bottom nuclear activation analysis techniques. (See Technology Transfer.) It is expected that a multiagency mission, using a submersible, may take place in 1977.

Project DUMAND (Deep Underwater Muon and Neutrino Detector) also is a multiagency effort— which began with modest NOAA/MUS&T-sponsored underwater cosmic-ray studies (FY-1973 MUS&T report). The effort now includes ERDA, NSF, and ONR. During this report period, results of the first 1976 DUMAND summer workshop, were compiled and a second workshop, September 1976, funded by ERDA, NOAA, NSF, and ONR, was held at the University of Hawaii. Concepts of the basic physics, instrumentation, data management, and undersea experiments tentatively proposed at the 1975 DUMAND Summer Workshop were consolidated. A multiagency experiment sequence was proposed, beginning with deep ocean surveys of bioluminescence and water turbidity. MUS&T has organized a group for Government Overview of DUMAND (GOOD) which will review and evaluate proposals by would-be DUMAND experimenters to participating agencies.

Also, previous cooperative efforts with Federal agencies and others led to a major study during this reporting period of the needs for supporting research to ensure the safety of diving for commercial activities relating to offshore energy development.

RESEARCH SUBMERSIBLE *ALVIN* SUPPORT

In October 1974, a cost- and use-sharing arrangement for the *Alvin* system was agreed upon by the Navy, NSF, and NOAA. The plan provides that each contribute one-third support to the *Alvin* operation for a 3-year period, beginning with 1975. Thus, *Alvin* is to operate as a national oceanographic facility under University National Oceanograph Laboratory System, with one-third of the available use-days for NOAA missions in fisheries and environmental research. The remaining two-thirds, funded by NSF and Navy, will be allocated for academic and scientific use on the basis of proposals reviewed by the scientific community. NOAA's use of *Alvin* is reported under Marine Science Applications.

The availability of the *Alvin* system to the scientific community over this 3-year period will be a valuable supplement to surface ships for conducting research. A main reason for the 3-year Navy, NSF, and NOAA support for *Alvin* is to determine the extent of research demand for it when adequate support is available.

SURVEY OF ICMSE AGENCIES

This section presents the results of a third review of the manned undersea activities of the Federal agencies and their use of manned undersea research submersibles and habitats under the direction of the Interagency Committee on Marine Sciences and Engineering (ICMSE). The report compares the availability and use of undersea platforms (submersibles and habitats) in the report period, and presents projected Federal agency use for such platforms. The survey of Federal agency utilization and requirements was made between July and October 1976, and also draws upon an international study of manned submersibles by the Oceanographer of the Navy and the Coast Guard made in June 1975 through September 1976 by R.F. Busby Associates, Arlington, Va.

The 12 ICMSE agencies were surveyed to determine their use of manned undersea assets during the time period July 1975 through December 1976. Unlike prior ICMSE surveys (December 1972 and April 1975), this survey was conducted by personal visits and telephone interviews rather than by a letter questionnaire. Selected agency individuals were asked the following questions:

1. For those programs within your sphere of responsibilities, which ones have used or plan to use manned undersea facilities (submersibles or habitats) within the July 1975 to December 1976 time frame?
2. If a shallow-water (less than 305 m) manned submersible were made available to your group, and its operational expenses defrayed under a UNOLS-type arrangement, what potential projects could you identify for such a facility?
3. Are there other individuals within your agency that should be contacted in this survey?

Results of the inquiry, and projections of the cost-effectiveness of a shallow-water vehicle operated under a UNOLS-type arrangement, will be completed in FY 1977. Two agencies, the Navy and Coast Guard, coordinated their responses and replied through one designated representative.

Reported Programs

This aspect of the ICMSE survey pertained to existing and planned programs for manned undersea platforms. It identified currently funded programs and manned undersea assets used. User agencies are defined as those who have supported or continue to support manned undersea programs by providing personnel, facilities, or operational funds.

Six of the 11 civilian member agencies of ICMSE identified active programs that involve manned undersea activities. ERDA, HEW, NASA, and the Department of State reported no active use of manned undersea assets within the July 1975 to December 1976 time frame of the survey. The six agencies supported 14 programs involving use of either submersibles or habitats. Three submersibles, *Alvin, Nekton Beta*, and *Nekton Gamma*, and one habitat, *HELGOLAND*, accounted for the total manned undersea assets used in the 14 programs. *Alvin, Nekton Beta*, and *Nekton Gamma* accounted for 282 submersible dives (142 dive-days). Military and private agency use of *Alvin* during the survey period account for an additional 107 dives in 102 dive-days. The number of dives and dive-days by these submersibles follows:

*Alvin**	88 dives	83 dive-days
Nekton Beta	104 dives	21 dive-days
Nekton Gamma	90 dives	38 dive-days

*Civilian ICMSE agency use only.

HELGOLAND (owned and operated by Gesellschaft fur Kernenergieverwertung in Schiffbau und Schiffahrt, mbH of West Germany) was the only habitat reported active in the period covered by this survey. MUS&T/NOAA sponsored two programs: the First International Saturation Study of Herring and Hydroacoustics (FISSHH) and Lubeck II. These accounted for 248 man-days (69 team-days) of bottom saturation time.

Navy programs requiring manned undersea platforms usually are satisfied by Navy-owned facilities. Only rarely does the Navy lease civilian owned or operated platforms, although the Navy was responsible for developing *Alvin* and continues to support its operations at Woods Hole Oceanographic Institution under a joint funding agreement involving the Office of Naval Research, NSF, and NOAA.

Potential Programs

Another purpose of the survey was to determine the potential use of submersibles within the ICMSE member agencies. The potential missions cannot and

should not be construed as having official sanction.

Ten of the twelve member agencies of ICMSE identified potential programs that may involve the utilization of manned undersea platforms (submersibles or habitats). The Department of State and NASA indicated they had no potential requirements for manned facilities. NASA personnel did indicate, however, that they have programs and continuing interest in the use of tethered, unmanned vehicles.

Sixty-two programs were identified as having potential requirements for manned platforms. Of these, 12 were identified by the Navy and 50 by the other 9 responding Federal agencies. Four of the civilian agencies (Smithsonian Institution, the Department of Interior, NOAA, and NSF) indicated that five programs have a potential requirement for a habitat, while HEW, ERDA, and Interior suggested three programs whose objectives may be better met by using a habitat rather than a submersible. Two agencies (NSF and NOAA) have programs that could use habitats.

The potential uses of manned undersea facilities are summarized as viewed by the agencies responding to the survey.

Programs That Are Potential Users of Manned Undersea Platforms

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (HEW)

Research and Develop Diver Standards

Examination of decompression theory and its practice as it pertains to proposed regulations for saturation diving; and the general health and safety of divers.

Point-of-contact: National Institute Occupational Safety and Health (NIOSH)

REMARKS: This program presently relies on data from other agencies.

Shellfish Safety

Investigation and certification of the safety of shellfish and shellfish beds as pertains to consumer health standards.

Point-of-contact: Food and Drug Administration (FDA)

REMARKS: Some monitoring of shellfish beds is presently done near dumping sites, but most of the activity concerns safety at the processing level rather than at the oceanic environment level. Submersible may be beneficial in the future. FDA generally relies on environmental data obtained by other agencies.

SMITHSONIAN INSTITUTION

Echinoderm Research

Continued research and observation of deep-sea echinoderms.

Point-of-contact: Department of Invertebrate Zoology (DIZ)

REMARKS: Has used *Alvin* by invitation and may use the Johnson *Sea Link* submersible of the Harbor Branch Foundation, which it has used previously.

Ichthyological Research

Observation and collection of Western Atlantic shell fish at depths greater than 200 ft.

Point-of-contact: Division of Fishes

REMARKS: No undersea vehicle utilization to date. Research objectives require diver lockout capability in order to make poisoned fish collections in deep rocky areas.

Mollusk Research

Research and capture of rare scallops.

Point-of-contact: DIZ

REMARKS: The study of the life history, behavior, and abundance of previously thought extinct scallops would require research to depths between 150 and 900 m.

Deep Reef Investigation

Observation and sampling of reefs and reef biota on reefs below scuba depth.

Point-of-contact: Department of Paleobiology.

REMARKS: At present, a habitat would be useful to increase the bottom time of divers engaged in drilling activities for the study of internal reef structure. A submersible would be of a lesser priority, but could be employed to observe and collect sample materials on deep reefs.

Tectonics and Pollution Studies

Study and investigation of tectonics and pollution in the Mediterranean Sea.

Point-of-contact: Department of Paleobiology

REMARKS: Have used submersibles and would continue to use them if operational funds could be secured. Submersible utilization has not been in the Mediterranean Sea.

NATIONAL SCIENCE FOUNDATION (NSF)

Research Facilities Support

In cooperation with the Navy and NOAA, provides block funds for *Alvin* operations to support undersea research by scientists from academic and scientific institutions. *Alvin* is a "National Oceanographic Facility."

Point-of-contact: Oceanographic Facilities and Support Branch.

REMARKS: Successful unsolicited proposals judged on a basis of scientific merit are granted *Alvin* dive time by the University National Oceanographic Laboratory System (UNOLS), an independent association of universities and institutions.

Oceanographic Research

The collection and analysis of physical, biological, chemical, and geological oceanographic data throughout the world's oceans.

Point-of-contact: Oceanographic Facilities and Support Branch

REMARKS: Responds to unsolicited proposals and may fund manned undersea facility utilization as part of overseas research program.

Marine Geology and Geophysics

Investigations of primary geological processes and their impact on the formation of the Earth's crust and the marine environment.

Point-of-contact: International Decade of Ocean Exploration

REMARKS: Two projects similar in scope to Project *FAMOUS* are being planned to study spreading centers—areas where the Earth's crust is being formed and altered—located off the Galapagos Islands and south of Baja California. The former program is closer to fruition.

ENVIRONMENTAL PROECTION AGENCY (EPA)

Radioactive Waste Disposal

Research waste management problems related to disposal of low-level radioactive wastes in the deep sea.

Point-of-contact: Office of Radiation Programs

REMARKS: Has participated on *Alvin* dives in 1976 on radioactive waste disposal sites near the active industrial waste Deepwater Dumpsite 106. Unmanned, tethered vehicles are also used.

Environmental Effects of Ocean Waste Disposal and Dredging

Studies to assess the effects and disposition of oceanic disposal of metabolic wastes, hazardous materials, and dredge spoils, and evaluation of inplace toxic substances with regard to removal/abandon decisions.

Point-of-contact: Marine Activities Division of Water Quality and Non-Point Source Control

REMARKS: Potential utilization for manned vehicles. None used to date.

Toxicological Experimentation

Interest in investigations and experimentation in marine toxicology and acquisition of background data on bottom communities.

Point-of-contact: Gulf Breeze Laboratory

REMARKS: Potential utilization for mannel vehicle; no present requirement.

Dredge and Radioactive Wastes

Interest in investigating dredge spoil sites and radioactive waste dump sites.

Point-of-contact: Narragansett Research Laboratory and Environmental Research Lab, Edison

REMARKS: Have used submersibles in the past. Could envision future use of manned platform if available, however, no programs present. In some circumstances, EPA data needs that require use of manned-facilities are met by NOAA.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (ERDA)

Diving Physiology Research

Research in occupational medicine emphasizing physiological aspects of diving, particularly oil industry diving.

Point-of-contact: Division of Biomedical and Environmental Research (DBER)

REMARKS: Conceivable use of manned platforms.

Ocean Thermal Energy Conversion (OTEC)

Multidisciplinary studies of: marine thermal resources, environmental monitoring, biota measurements, site studies, impact assessment, test and evaluate OTEC instrumentation.

Point-of-contact: Division of Solar Energy

REMARKS: Definite requirement for a submersible platform.

Seabed Waste Disposal

Assessment of the possibility and advisability of using geologic structures for the disposal of radioactive wastes on the floor of deep oceans.

Point-of-contact: Division of Environmental Control Technology

REMARKS: Program is not in the engineering phase at present. Submersible may be useful in evaluating specific sites.

Oceanic Wind Turbine Research

Research into the feasibility and technical aspects of generating electrical power by oceanic wind turbines.

Point-of-contact: Division of Solar Energy

REMARKS: Initial research has just begun and although certain aspects of the program may possibly involve utilization of manned vehicles, the requirement is not obvious at this time.

Mariculture Research

Location and examination of sites for potential kelp cultivation.

Point-of-contact: DBER

REMARKS: Could use shallow-water vehicle.

Nuclear Research Applications

Retrieval of nuclear untethered unmanned research vehicle. Placement, inspection, servicing, and retrieval of a conceptual ocean bottom nuclear power supply (for use in recovery of offshore oil).

Point-of-contact: Administration for Nuclear Energy

REMARKS: Possible use of manned undersea facilities when program is firmly established. May involve under-ice operations.

Technical Programs

Study the character of, and monitoring of, effluents and pollutants and their transport and transfer resulting from the siting of energy-related facilities on the sea floor.

Point-of-contact: DBER

REMARKS: Could use shallow-water manned vehicle if available.

Research and Development of Pollutant-Specie Analysis Equipment

Test and evaluation of equipment to study X-ray fluorescence for pollutant analysis, laser techniques for specie determinations, neutron-activation techniques to determine mineral presence at economic levels. Also determination of trace organics using gas chromatography mass spectrophotometer.

Point-of-contact: ERDA

Participating: Battelle Northwest Laboratories, Radiological Sciences Department

REMARKS: Submersible use is being planned for these efforts.

Effluent Monitoring

Monitoring the effects of offshore drilling activities. Biological/chemical research adjacent to nuclear powerplants discharging effluents into the ocean.

Point-of-contact: ERDA

Participating: Battelle Northwest Laboratories, Radiological Sciences Department

REMARKS: Could use shallow-water vehicle.

U.S. ARMY CORPS OF ENGINEERS

Resource Assessment

Sand and gravel resource assessment of the Inner continental shelf and in the Great Lakes.

Point-of-contact: Coastal Engineering Research Center (CERC)

REMARKS: The general feeling is that standard (surface ship) operational methods are sufficient, but a shallow-water submersible might play a role at some point.

Construction, Monitoring, and Observation of Offshore Facilities

Long-term monitoring and observation of undersea construction programs, bottom conditions, and dynamics and scour action around marine structures.

Point-of-contact: Coastal Engineering Research Center

REMARKS: Same remarks as for Resource Assessment.

Arctic Ice Scoring Investigations

Investigation of morphology of Arctic Sea ice cover and ice scoring on Arctic shelves regarding proposed bottom wellheads and pipelines.

Point-of-contact: Cold Regions Experimental Laboratory

REMARKS: Would require vehicle for under-ice observations or observations of contemporary ice scoring.

Reconnaissance of Dredge Spoil Activities

Investigate the impact of spoils on the ocean floor and the dynamics and effects of the resultant dispersion of those spoils.

Point-of-contact: Waterways Experimental Laboratory

REMARKS: The field portion of this program is phasing out; therefore no requirements exist for manned vehicles.

Dredge Disposal Management

Biological and geological census of offshore dredge material disposal sites to establish criteria for the suitability of proposed sites and follow-up monitoring for these areas.

Point-of-contact: Northeast Division, U.S. Army Corps of Engineers

REMARKS: Have employed manned submersibles.

DEPARTMENT OF THE INTERIOR

Fresh Water Fish Research

Study population dynamics, abundance, life cycles, and spawning behavior of sport fish; behavioral studies, effect, control, and eradication of the sea lamprey in the Great Lakes; and the effect of environmental changes on fish populations.

Point-of-contact: Fish and Wildlife Service

REMARKS: The program has not used undersea vehicles in the past, but such facilities could be useful for this effort.

Recreational Area and Facility Development

Education of the general public within marine recreational areas by direct observation of aquatic life and geologic structures.

Point-of-contact: Bureau of Outdoor Recreation

REMARKS: Use and availability of a manned subsurface platform is viewed as remote for this application; possible applications are to be considered as program proceeds.

Marine Mammal and Sea Bird Research

Observation of activities, behavior feeding characteristics, and prey of marine mammals and sea birds.

Point-of-contact: Fish and Wildlife Service

REMARKS: This program is not funded for undersea vehicles, but such facilities would be useful for operation in cold weather regions.

Monitor Ocean Utilization Activities

Observe the biological impacts of OCS energy exploration and production activities, dredge spoil disposal areas, and bottom life in dredged navigation channels.

Point-of-contact: Fish and Wildlife Service

REMARKS: Although the opportunity for submersible utilization in this program is minimal, such utilization is felt needed and desired.

Geophysical Research

Investigation of bottom transport, sediments, sedimentological processes, mineral formation/concentration, deep ocean geophysics, biological assessments, and oceanographic and geologic environment of outer continental shelf and slope areas. Would include pipeline studies, bottom stability studies for offshore structures, and reef surveys.

Point-of-contact: Geological Survey

REMARKS: Various USGS personnel have utilized manned submersibles funded by BLM, NOAA, and USGS. Have requirements for continued use of manned undersea facilities.

Arctic Research

Multidisciplinary investigations involving sampling, observation, and instrumentation testing, as well as site studies related to resource and energy development in the Pacific Arctic area.

Point-of-contact: Geological Survey

REMARKS: These programs would require use of undersea platform to make detailed investigations of specific sites. Interest ranges through nearly the complete spectrum of ocean and ocean-bottom investigations.

Marine National Park Development

Projects include multidisciplinary inventories and assessments of present and future marine park areas. There is also interest in monitoring and study of coastal dynamics and beach erosion and instrumentation of dynamic or potentially dangerous areas.

Point-of-contact: National Park Service (NPS)

REMARKS: Definite interest in use of shallow-water vehicle, particularly a habitat.

Submarine Canyon Investigations

Study the interaction of bottom and near-bottom currents and benthic fauna activities on the erosion of walls and floor of canyons and geologic structures in general.

Point-of-contact: Geological Survey

REMARKS: This project has employed manned submersibles through UNOLS.

Water Resource Research

Coordination of research in water resources and development of these resources. Could include dam inspection, observation of siltation and siltation rates, studies of corridor routes, and inspection of underwater aqueducts.

Point-of-contact: Bureau of Reclamation

REMARKS: These programs have not used manned undersea facilities. Potential application is recognized.

Outer Continental Shelf Studies

Gather multidisciplinary data base for management of OCS energy activities; includes task selection, lease stipulations, format of operational orders, and environmental impact procedures/statements.

Point-of-contact: Bureau of Land Management

REMARKS: BLM actively funds and plans to continue funding other agency efforts and submersible time in order to secure the required data.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Marine Mining and Mineral Assessment

Inventory offshore sand, gravel, and phosphorite resources, environmental assessments of surface and subsurface sediment plumes generated by the mining processes for these resources.

Point-of-contact: Office of Marine Minerals

REMARKS: If these programs come to fruition, manned facilities could be effectively utilized.

Ichthyological Census

Determine correlation of fish speciation and populations between surface collection methods (trawls) and in-situ observation; investigate speciation, diversity and abundance of fish with respect to changes in bottom topography.

Point-of-contact: Systematics Laboratory

REMARKS: Have used *Alvin* through NOAA participation in UNOLS support.

Submarine Canyon and Sedimentation Research

Defines sedimentary processes active in submarine canyons and on the adjacent continental shelf; includes geological and biological bottom environment assessments of the areas.

Point-of-contact: Atlantic Oceanographic and Meteorological Laboratories.

REMARKS: MUS&T has funded vehicle utilization for this program.

Fisheries Research

Ecology and stock assessment of megabenthos of New England continental shelf. Investigate herring spawning sites and their hydroacoustic characteristics, fish behavior, and trapping methods.

Point-of-contact: National Marine Fisheries Service (NMFS)

REMARKS: Will continue to employ submersibles and have used habitat funded by MUS&T.

Crisis and Yield Investigations

Monitor and determine causes of reported fish kills; survey commercial bivalves.

Point-of-contact: NMFS

REMARKS: Manned submersible services required.

Reef Investigations

Study of coral reefs off North and South Carolina. Such live bottom studies would involve environmental characteristics, reef growth, reef inhabitants, and their behavior and distribution.

Point-of-contact: NMFS and Bureau of Land Management

REMARKS: Habitat potentially useful for this program when implemented.

Manned Undersea Science and Technology (MUST&T)

To develop, promote, coordinate and support a national, civilian operational capability for man to work under the sea to achieve better understanding, assessment and use of the marine environment and its resources. To conduct operations supportive of DOC missions in the fields of living resources and environmental surveys; nonliving resources, geology, and processes; marine management and pollution; and

international-national scientific cooperation. To transfer and develop manned undersea technology for cost-effective civilian application.

Point-of-contact: MUS&T Office

REMARKS: Provides university, industry, and government scientists and engineers with access to facilities and specialized support; cooperative efforts with many ICMSE member agencies; technology development mission; and primary funding group for manned facilities.

Office of Sea Grant

Sea Grant colleges conduct research in marine environment applicable to development of marine resources and technology and understanding and assessing offshore pollution. Provide education, training, and advisory services.

Point-of-contact: Office of Sea Grant

REMARKS: Responds to Sea Grant proposals and may fund vehicle utilization as part of overall research; coordinates manned undersea requirements with NOAA/MUS&T; no specific fund set aside for vehicle use.

Scientific Diving Capabilities

Develop scientific diving capabilities to edge of continental shelf including saturation diving; operation of in-situ chemical and biological instrumentation; and multidisciplinary investigations.

Point-of-contact: MUS&T Office

REMARKS: Has employed habitats to conduct studies.

Observation and Evaluation of In-situ Instrumentation

Observe, maintain, and evaluate performance of in-situ bottom-mounted scientific equipment for the gathering of physical and geologic data in the coastal zone and on the continental shelf.

Point-of-contact: National Ocean Survey

REMARKS: Under certain circumstances, a submersible would be useful.

Marine Atlas

Collection of biologic, geologic, and hydrologic data on the ocean floor for the construction of a data atlas covering the coastal zone and continental shelf.

Point-of-contact: National Ocean Survey

REMARKS: See remarks as for Observation and Evaluation of In-situ Instrumentation.

DEPARTMENT OF THE NAVY

Submarine Location, Escape, and Rescue

Development of a capability to locate a distressed submarine and rescue surviving personnel.

Point-of-contact: Naval Ships Systems Command

REMARKS: Navy requirements are generally met by Navy-owned systems. Deep Submergence Systems Project (DSSP) developed Deep Submergence Rescue Vehicles (DSRVs). Unmanned, tethered assets, such as *CURV*, can also be used.

Deep Ocean Technology

Advancement of the state of technology in the area of undersea operations and materials, including manned undersea operations. Upgrade *Sea Cliff* DSV for 6,069-m operations. Expand ocean engineering construction capability. Develop unmanned, untethered assets.

Point-of-contact: Naval Materiel Command

REMARKS: Primarily oriented toward removing man in routine operations by the use of remote systems. Manned systems used in support of the development.

Man-In-The-Sea, Continental Shelf

Development of techniques, diver tools, and diver life-support equipment to enable divers to safely work at depths to 762 m in support of Navy operations.

Point-of-contact: Naval Ships Systems Command

REMARKS: Surface-based support with personnel transport chamber to dive worksite.

Deep Submergence Biomedical Development

Conducts biomedical research and development of improved medical support to ensure safe, effective manned undersea activity by present and future naval operations.

Point-of-contact: Bureau of Medicine and Surgery

REMARKS: Studies of biomedical and physiological effects of diving; cooperative projects with NOAA-MUS&T, Department of Health, Education, and Welfare.

Large-Object Salvage System

The research, development, test, and evaluation of systems to provide an improved capability to salvage large objects from water depths to 305 m.

Point-of-contact: Naval Ships Systems Command

REMARKS: Development project currently at operational evaluation stage.

Deep Ocean Engineering and Research

Operation of the submersible *Alvin* and the support ship *Lulu* by Woods Hole Oceanographic Institution in support of ocean science and deep-ocean engineering research.

Point-of-contact: Office of Naval Research.

REMARKS: Provides support for *Alvin* and related research; no other platform utilization programed.

Advanced Marine Technology

Development of tools and equipment for the submersible *Alvin* to further the capability to conduct scientific and engineering research and to test equipment, and funding to develop ocean research techniques.

Point-of-contact: Office of Naval Research

REMARKS: Supports research tools for *Alvin*.

Operational Underwater Salvage

Maintains a Navy capability to conduct salvage as required for national security, failure analysis, and safety of navigation.

Point-of-contact: Naval Ships Systems Command

REMARKS: May lease civilian-operated platforms in an emergency. Requirements generally satisfied by Navy platforms.

Fleet and Facilities Support

The installation, operation, and maintenance of facilities, weapons, and navigation calibration systems to support the operations and readiness of the fleet.

Point-of-contact: Naval Facilities Engineering Command

REMARKS: Includes operation of Navy platforms: *Turtle, Trieste, Sea Cliff,* and *NR-1*.

Acoustic Studies

The study of ocean stability, ocean floor, and subfloor characteristics, biological populations, and ambient noise as related to acoustics.

Point-of-contact: Naval Oceanographic Office

REMARKS: R&D programs support costs of needed platforms as required.

Development of Ocean Engineering and Construction Techniques

The study of soil characteristics as related to underwater construction and breakout; the grading of the sea floor for construction; and the engineering and assembly of underwater facilities.

Point-of-contact: Naval Civil Engineering Laboratory

REMARKS: Minimum use of manned and unmanned underwater systems. R&D projects support costs of platforms as required.

Exploratory Development Projects

Conducts efforts directed toward the solution of specific problems short of major prototype development, to improve diver life-support equipment and tools, and projects such as the development of underwater construction techniques which require diver support, tools, energy source, and conversion.

Point-of-contact: Oceanographer of the Navy

REMARKS: Composed of approximately 12 separate funded and identifiable tasks.

DEPARTMENT OF TRANSPORTATION

Underwater Safety Program

Plan for the safety of nonmilitary undersea activities through vessel and station regulation and inspection; maintain knowledge of ongoing undersea operations; and provide undersea search and rescue (SAR) services. Manage frequency allocations in the undersea acoustic communications frequency spectrum. Coordinate Coast Guard undersea mission support.

Point-of-contact: Coast Guard

REMARKS: Potential for issuing regulations on diving and facilities; may lead to a civil rescue capability; may require occasional platform use.

SUBMERSIBLE SAFETY

In the construction and utilization of submersibles, safety is of paramount concern. The Coast Guard considers safety in two elements: accident prevention and rescue/recovery operations. Much can be done in designing a safe submersible to reduce the chance of having an accident and to facilitate survival and recovery after an accident. Therefore, an important consideration in submersible safety is designing, building, and testing the system in accordance with a recognized certification or classification code. Insurance companies often consider this a criterion in underwriting coverage. U.S. Navy certification requirements for submersibles are more stringent and qualifying than are the guidelines for classification. NOAA requires that all the U.S. submersibles it leases must have ABS classification or U.S. Navy certification. This establishes an acceptance level of submersible characteristics and capabilities, including design and construction integrity, safety and emergency

capabilities, and proof of hydrostatic testing. Depending on the NOAA mission, various other requirements, such as the extent of life support, endurance, type of communications, are often stipulated beyond ABS minimums.

Several items in the *ABS Classification Manual* are listed as design guidelines rather than requirements, and the classification process relies heavily on design review and observation of tests by an inspector. The lack of specific requirements could result in variations in equipment design and selection and hence incompatibilities with equipment on other submersibles or vessels deployed to assist in rescue. Therefore, it is important to consider some degree of standardization and compatibility between a rescuer and an endangered platform. After an accident, for example, it is essential that sufficient life support be on hand while waiting for assistance and that means be provided for signaling and communicating with the rescue forces. Also essential are some devices and procedures for hooking or grasping a submersible to enable its recovery from a surface vessel. A number of rescue vehicles and devices built by various companies in the U.S. and abroad may be capable of recovering a specific submersible, but may not be compatible for use with other submersibles. This is a matter of great concern since a call to assist will be directed at whatever platform is available for rescue.

The activity in the undersea vehicle field now centered in the North Sea area is expected to shift as exploration of U.S. domestic sources of subsea energy expands. Development of safety standards for construction, equipping, and operation of undersea vehicles, as well as coordination of rescue efforts in the case of distressed submersibles, is the responsibility of the Coast Guard.

NOAA has joined with the U.S. Navy to support the Coast Guard's Underwater Safety Project in the Office of Merchant Marine Safety in its contract with the Marine Technology Society. The results of the contract will include input from leading experts in the submersible industry from the United States, Canada, and Europe and will be published as the third volume in the MTS series, "Safety and Operating Guidelines for Undersea Vehicles." Included will be input to an international symposium to improve the operating safety of undersea vehicles and rescue response activity. The symposium will be preceded by meetings in which groups (composed of experts in the undersea vehicle field) will draft standards for the safe operation of undersea vehicles. The symposium will produce (on the basis of the draft standards) international consensus safety standards for undersea vehicles.

DIVING SAFETY

As noted in the Marine Board report discussed in Requirements and System Analyses, diving safety is the area where national and NOAA needs most nearly coincide. As discussed in previous MUS&T reports, MUS&T funding of research on shallow saturation decompression tables and tables for excursion dives from a saturation base has produced useful decompression schedules for this type of diving, and could only have been done with the cooperation of the U.S. Navy. Standards and operation criteria for the safety of NOAA divers were printed in the *NOAA Diving Manual*. MUS&T has continued close cooperation with the U.S. Navy biomedical and diving physiology research efforts.

NIOSH Diving Task Force

Shortly after its formation, NOAA began work with the National Institute for Occupational Safety and Health (NIOSH) in the Department of Health, Education, and Welfare concerning the safety standards for commercial divers. MUS&T assisted in the establishment of a NIOSH Diving Task Force which issued in June 1975 a "NIOSH Plan for the Safety and Health of Divers Associated with Subsea Energy." Representatives on this task force also included members from ERDA, the National Heart and Lung Institute, the U.S. Navy, the Association of Diving, Interior, the United Brotherhood of Carpenters and Joiners of America, AFL/CIO, and from a number of universities. This report suggested a series of projects including:

1. National plan for safety and health of divers
2. Medical and operating standards
3. Manpower development (physicians, paramedics, and life-support training)
4. Hyperbaric treatment guidelines
5. Surgical and medical treatment of divers under pressure
6. Saturation, nonsaturation, and excursion protocols to 1,000 ft
7. Saturation and excursion diving to 1,000 ft
8. Application of diving research protocols
9. Epidemiology study
10. Data bank and registry
11. Literature consulting service
12. Feasibility studies of diving beyond 1,600 ft. of seawater.

National Plan for Safety and Health of Divers

The first project was completed in January 1976 by the Undersea Medical Society under Contract 210-75-0078 from the National Institute for Occupational Safety and Health with funding support from the Energy Research and Development Administration, NOAA, the National Heart and Lung Institute, and the Environmental Protection Agency (EPA). A comprehensive report, "National Plan for the Safety and Health of Divers in their Quest for Subsea Energy," is

available from the Undersea Medical Society, Inc., 9650 Rockville Pike, Bethesda, Md., 20014.

The 20 topics called for in the National Plan contract were divided into four categories as listed below:

Selection and Training

Psychological Factors Involved in Undersea Hyperbaric Exposures (Retitled—Selection and Training of Professional Divers)

Medical and Paramedical (Retitled—Selection and Training of Physicians and Paramedics for Offshore Diving)

Administrative

Legal and Compensatory Aspects

Technological

Compression and Decompression Protocols

Systems Design Criteria

Monitoring Techniques

Biomedical

Audio/Vestibular Derangements

Osteonecrosis

Subtle Physiological Changes

Respiratory/Pulmonary Function in Hyperbaric Exposures

Cognitive and Psychomotor Performance

Exchange of Inert Gases, Oxygen, and Carbon Dioxide

Use of Gases Other Than Nitrogen and Helium (Retitled—Assessment of Gases Suitable for Diving)

Physiological and Toxic Effects of Respiratory and Contaminant Gases (Acute and Chronic)

Oxygen

Use of Drugs and Other Medical Treatment Under Hyperbaric Conditions

High Pressure Nervous Syndrome

Microbiological Aspects

Thermal Problems

The Undersea Medical Society (UMS) report included the following comments:

The chairmen of individual workshops convened for each of the above topics unanimously agreed that the highest priority should be given to more careful selection and training of professional divers. Recommendation in the UMS final report related to the selection or training of divers involved in deep-sea diving is included in this general recommendation and should therefore receive the highest priority.

Second priority was given to the problem of medical and paramedical care for the crews and divers on oil rigs and platforms. This includes selection, training, and deployment of physicians and paramedics, the development of appropriate rescue vehicles, and the establishment of shore-based hospital treatment facilities.

The chairmen of the committees were also unanimous in recommending the establishment of a coordinating body in the civilian sector whose functions would be similar to those of the Office of Naval Research for the Navy. Such a coordinating agency could provide a stable funding base, evaluate changing priorities, and in general unify undersea research in safety and health. It may not be necessary to establish a new agency to perform these tasks; expanding the functions of an established group, such as the National Oceanic and Atmospheric Administration, might be both feasible and efficient.

ERDA Support for Diving Safety Research Project

The Division of Biomedical and Environmental Research in ERDA agreed in the latter part of FY 1976 to provide funds to NOAA to begin implementation of the priority items cited in the UMS National Plan. Two contracts were awarded by the Department of Commerce.

Contract 6-35348 to Florida Institute of Technology: A contract to the Florida Institute of Technology, Jensen Beach, Fla., to support the development of a program leading to an Associate of Science Degree in Underwater Technology. The program has currently over 60 students enrolled in the first-year class, which commenced in January 1976. The grant is for the purpose of supporting the hiring of additional staff, purchasing needed equipment, and generally assisting a program being jointly funded by government, industry, and the university. The results of the program will produce highly skilled technicians and technologists to work with industry and the Government in pursuing the quest for subsea energy.

Contract 6-35349 to Undersea Medical Society: A contract to the Undersea Medical Society (UMS), Bethesda, Md., to 1) establish the initial methodology and management training for physicians in the field of hyperbaric medicine and 2) to conduct a comprehensive analysis of emergency medical technician/diver (EMT/D) training available in the United States. UMS shall establish a system of evaluations of graduates of such training courses.

It is expected that additional reimbursable funds will be provided by ERDA to NOAA/MUS&T to implement additional programs in support of the National Plan. To facilitate interagency review and direction, MUS&T will establish a Federal Diving Research Task Force to review research requirements, and establish a method of project review and priority establishment. MUS&T will continue to interact with concerned elements of this private, academic, and labor section concerned with diving safety.

OSHA Commercial Diving Standards

On June 15, 1976, the Assistant Secretary of Labor for Occupational Safety and Health issued an Emergency Temporary Standard (ETS) for Diving Operations (41 FR 24272) as Subpart T of 29 CFR. Part 1910, Sec. 1910.401 et seq. It was issued pursuant to sections 6(c) and 8(c) of the Act, Secretary of Labor's Order No. 8-76, and 29 CFR Part 1911.

The background and reasons supporting issuance of the ETS and discussing its provisions were set forth in 41 FR 24272-24285. On August 8, 1975, a petition by the United Brotherhood of Carpenters and Joiners of America, AFL-CIO, was presented to the Secretary stating its belief that a situation of grave danger existed within the diving industry and urging that an ETS be issued with respect to diving operations to protect exposed employees. An informal fact-finding hearing was convened by OSHA in Washington, D.C., November 11-14, 1975. In conjunction with OSHA's evaluation of the data gathered during such hearings, a Federal interagency task force in which NOAA/MUS&T participated was assembled to provide technical support to OSHA with respect to a possible operational safety and health standard for commercial diving operations. Supplementing this effort, OSHA consulted with several independent diving experts on a number of subjects pertinent to the regulatory effort. Based on the evidence gathered, the Assistant Secretary determined, in accordance with section 6(c) of the Act, that divers were being subjected to grave dangers from toxic substances and harmful physical agents, as well as from new hazards, and that an ETS was necessary to protect the exposed employees from such danger.

The ETS was to have been effective on July 15, 1976. However, on August 11, the U.S. Court of Appeals for the Fifth Circuit issued an indefinite stay of the ETS pending a final decision on its validity, "*Taylor Diving and Salvage Co., Inc. et al.* v. *U.S. Department of Labor*,' Civil Action No. 76-2886 (CA 5, 1976). As of the date of this publication, the Court has not yet ruled on the merits of the ETS. Pursuant to the court order, the ETS has not been enforced by OSHA.

To develop the proposal for a permanent standard, the Federal interagency task force was reassembled with representation from OSHA, the U.S. Coast Guard, the U.S. Navy, the National Institute for Occupational Safety and Health (NIOSH) of HEW, NOAA, and the Smithsonian Institution. Individuals were assigned to the task force by their respective agencies for the purpose of providing technical and scientific support; as such, their participation was not intended to represent agency endorsements of the OSHA proposal.

In formulating a proposed permanent standard, OSHA reevaluated the substantive provisions of the ETS in light of all the information relied on and referred to in the ETS and additional information made available to the agency since publication of the ETS. In addition to public comments which have been received on the ETS and recommendations from experts, other sources of information have included the final draft of a proposed standard and supporting technical narrative of the NIOSH-Undersea Medical Society-Tarrytown Labs, Ltd. project on "Recommended Medical and Operating Standards For Divers" (August, 1976), and the July and September 1976 "ballot" drafts of a proposed voluntary standard being developed by the American National Standards Institute's Z-135 Committee on Safety in Commercial and Industrial Diving Operations.

Inasmuch as many diving operations are closely associated with, or related to, construction activities, OSHA deemed it appropriate to seek the advice and recommendations of the Advisory Committee on Construction Safety and Health established under the Construction Safety Act (the Advisory Committee) prior to OSHA's formulation of a proposal.

In August 1976, the Advisory Committee met formally to discuss materials and information relating to the occupational safety and health aspects of commercial diving operations. On August 9 and 10, OSHA presented to the Advisory Committee, in addition to the provisions of the ETS and background material, the major concepts contemplated for inclusion in the new proposal. On August 26 and 27, the Committee considered an OSHA draft proposal which was prepared for the Advisory Committee and made available to the public in advance. During the Committee's deliberations, a significant number of oral and written comments were presented by persons representing various sectors of the diving community.

Pursuant to a Memorandum of Understanding between U.S. Coast Guard (USCG) and OSHA, dated June 9, 1976 (41 FR 24291, June 15, 1976), the USCG intends to publish a notice of proposed rulemaking which will be substantively in agreement with this proposal.

INTERNATIONAL ACTIVITIES

U.S. and foreign civilian science and technology diving practitioners have many problems and interests in common. The MUS&T group has worked with foreign marine scientists in technology exchange, the shared use and loan of underwater facilities, and data transfer.

The major international cooperative effort during FY 1976 consisted of the German, Polish, and United States joint program off Rockport, Mass., in the autumn of 1975, using the German underwater laboratory *HELGOLAND* as the habitat center for a variety of diving missions. Another science and technology mission in which U.S. divers participated also used the *HELGOLAND* during June and July off Lubeck, FRG.

Cooperation with Japanese scientists continued in diving physiology and technology.

PROJECT FISSHH

Habitat: *HELGOLAND*

Purpose of program: First International Saturation Study of Herring and Hydroacoustics (FISSHH). Ecological study of a herring spawning site, study of fish behavior and fish trapping methods, initial test of hydroacoustic calibration system, and advancement of scientific diving capabilities.

Location: Jeffreys Ledge, Gulf of Maine

Dates: September and November 1975

Duration: 164 man-days of bottom saturation time (41 team-days)

Depth: 34 m

Sponsor: NOAA/NMFS-Northeast Fisheries Center, MUS&T

Participants: NOAA, Coast Guard, Navy, Federal Republic of Germany, Poland, Soviet Union, and various university personnel.

The National Oceanic and Atmospheric Administration (NOAA) has been conducting a number of long-term research programs concerning herring and other pelagic fishes in the Gulf of Maine and Georges Bank areas off New England. The studies have involved the use of man-in-the-sea techniques including the use of research submersibles and scuba diving from trawlers, as well as ship-based hydroacoustic and dredging studies. A number of the research efforts have been under the auspices of the International Commission of Northwest Atlantic Fisheries (ICNAF), an association of 18 countries that establishes catch quotas for various fish species in the area.

Of particular importance to the commercial fisheries in the Northwest Atlantic is the herring (*Clupea harengus harengus* L.). Annual landings by U.S. and foreign fishermen in the last few years have exceeded 1 billion pounds—the largest biomass of any single species in the New England region. U.S. fishermen have historically concentrated on juvenile herring, marketed in the United States as "sardines," while other nations fished the adults. This trend is now changing, and U.S. fishermen also depend upon the adult. The degree to which either of these fisheries may affect the other is not well understood. Research by the ICNAF nations has concentrated on the seasonal distribution of the harvestable sizes, and the age composition of the stocks. The United States has studied the growth and distribution of the larvae to define separate stocks. A major gap in our present understanding of what factors affect the yield of the herring resource is our comparative ignorance of their early life history. During their early life they are continually preyed upon, and dispersed and transported by ocean currents. There is a general consensus among herring biologists that the events which occur during these early stages determine the abundance of a given year class when it is taken by the commercial fishery one or more years later.

Hydroacoustic techniques for measuring fish populations consist of echo sounders that transmit sound pulses and receive echoes from fish, and computers that convert the fish echo data into estimates of the abundance of the fish targets. It is also possible for experts to identify the species of fish by analyses of the sound "signature." When the estimates are accurate, hydroacoustics is a much more rapid method of measurement than conventional methods such as tagging or analysis of commercial catches. Hydroacoustic equipment for fisheries surveys is developed by several ICNAF nations and is basically similar.

Background

The international fisheries research program completed in the fall of 1975 represented the latest extension and combination of three ongoing marine series of studies sponsored by NOAA over the last 5 years. The first study was a series of cooperative man-in-the-sea projects in waters off the northeast coast of the United

States, conducted by NOAA's MUS&T Office and the Manned Undersea Research and Technology activity of NOAA/NMFS's Northeast Fisheries Center (NEFC) at Woods Hole, Mass. The cooperative projects began in September 1971, when NEFC biologist divers, together with scientists from the Massachusetts Division of Marine Fisheries and the Maine Department of Sea and Shore Fisheries, used the Perry *PC-8* submersible in a series of 33 dives to depths of 228 m (750 ft) in surveys of herring spawning sites in the western Gulf of Maine. The physical characteristics of historical spawning sites were observed, as were schools of adult herring. In June 1972, the lockout research submersible Perry *Deep Diver* was used in a series of 29 dry dives and 19 lockout dives to depths of 91 m (300 ft). Scientists from the Fisheries Research Board of Canada, Environmental Protection Agency, and Maine Department of Sea and Shore Fisheries joined NOAA diver scientists to acquire extensive training in deep-sea diving and to study offshore lobster and northern shrimp. In October 1972, using two leased fishing trawlers, trawl collections and scuba dives to depths of 43 m (140 ft) were made over a period of 28 days. A preliminary survey of Jeffreys Ledge spawning areas and investigation of the early life history of the herring were made, but direct in-situ observations were restricted by depth limitations on the scuba divers in the Gulf of Maine (Boyar et al. 1973). In October 1973, the research submersible *Nekton Gamma* made 25 dives of work-time periods up to 2-1/2 hours to define ecological factors from depths of 29 to 91 m (95 to 300 ft). The in-situ observations were the first to be correlated with plankton and hydrographic station data in known spawning areas. During October 1974, NEFC scientists made a complete survey using scuba diving techniques off Rockport, Mass., at the location which became the site for Project FISSHH (First International Saturation Study of Herring and Hydroacoustics) in 1975.

Prior to the beginning of the use of the *HELGOLAND* underwater laboratory, a series of 35 submersible dives were made in September 1975 by fisheries scientists from NOAA's Northeast Fisheries Center using the General Oceanographic's *Nekton Beta* at the dive site and nearby herring spawning grounds.

The second series of ongoing marine research programs was the exchange of international cooperation in ongoing research efforts using saturation diving techniques. During the Third International Man-in-the-Sea Symposium held at Helgoland in September 1972, MUS&T personnel began discussions regarding joint missions with the operators of the underwater laboratory *HELGOLAND*—Gesellschaft fur Kernenergieverwertung in Schiffbau und Schiffahrt, mbH (GKSS), one of the major research and development corporations in the Federal Republic of Germany (FRG), with marine facilities at Geesthacht, near Hamburg. NOAA sponsored participation of NEFC scientist divers and University of New Hampshire participants at a joint saturation-diving mission on the *HELGOLAND* in July 1973. Continuing bilateral cooperation included divers and scientists from GKSS, University of Kiel, and the University of Bochum, all participating in the Bahama Banks Research Program using the Perry *HYDROLAB* off Freeport, Grand Bahamas, in May 1974. During August 1974, a multinational marine science mission was held using the *HELGOLAND* off Lubeck, FRG, with scientists from Germany, France, the United Kingdom, and the United States participating.

A third series of marine research programs involved hydroacoustic research by ICNAF countries. Ships from Federal Republic of Germany, the German Democratic Republic, Poland, and U.S.S.R. have participated in hydroacoustic research efforts in the Gulf of Maine.

The depth of the herring beds discovered near Rockport, Mass., in September 1974, and the cold water and severe weather that could prevail during the herring spawning season, required using the GKSS underwater laboratory *HELGOLAND* with its unique technological capabilities. Discussions concerning its use began with GKSS in late 1974. The Polish Fisheries Central Board, Szczecin, Poland, agreed to transport the *HELGOLAND* system to the United States. The FRG agreed to loan the *HELGOLAND* for the autumn mission in the Gulf of Maine. The MUS&T office then, in early 1975, began preparing for its role of providing funding, management, coordination, and logistics for the international FISSHH mission. Objectives of this mission were to:

1. Study the ecology of North Atlantic herring spawning grounds and define the ecological factors that affect survival of the herring.
2. Perform hydroacoustic experiments on target strength of pelagic fishes.
3. Perform experiments on the behavior and trapping of fish.
4. Develop deep scientific diving capabilities in cold water and open sea conditions in northern latitudes.

Participants

Project FISSHH involved over 60 participants from the Federal Republic of Germany, Poland, the U.S.S.R., and the United States. *HELGOLAND* and its operational crew of 15 was supplied by GKSS of the Federal Republic of Germany. The Polish factory ship *Pomorze* transported the laboratory and German and Polish diver scientists to the United States in early September. The research vessels *Albatross IV* and *Atlantic Twin*, the RV *Advance II* with the research submersible *Nekton Beta*, and support vessels *Galatia, Phalarope, Flying Fish,* and *Barbara L.* were supplied by the United States. All land-based support was furnished by the United States. Of the 34 diver scientists-technicians in the program, 3 were Polish, 8 were German, and 23 were American. Guest scientists came from five American universities, the Army Corps of Engineers, and four

NOAA laboratories. Diver scientists from the West German Biologische Anstalt Helgoland, University of Turkey, Sea Fisheries Institute of Gdynia (Poland), and Trondheim University (Norway) either participated or were scheduled to participate. Three participants from U.S.S.R. came for testing of the hydroacoustic equipment developed by the Draper Laboratory in conjunction with NOAA's Northeast Fisheries Center.

Major assistance was provided by the U.S. Navy, and in particular, by the Portsmouth Naval Shipyard's Boston Caretakers Group, at the former Charlestown Naval Base where the *Pomorze* offloaded the *HELGOLAND*. The U.S. Navy also permitted Captain George F. Bond, M.D., the father of saturation diving, to serve as Project Medical Director. The U.S. Coast Guard tender *Spar* and the cutter *Whiteheath* rendered valuable assistance during emplacement and recovery of underwater equipment. The location for the project, Rockport, Mass., with nearby Gloucester, has been a center for the commercial fishing industry.

Underwater Laboratory *HELGOLAND* System

The *HELGOLAND* Underwater Laboratory was conceived in 1966 by the German Institute of Aviation Medicine and the Biological Institute of Helgoland. The laboratory was funded by the Ministry for Education and Science of the Federal Republic of Germany (FRG), and was designed and constructed in 9 months in 1968. Its first mission was in 1969. It was overhauled and modernized in 1971 and operated in Eckenfords Harbor. In 1972, technological responsibility was transferred to GKSS, which operated the laboratory at Helgoland in 1973, after adding a wet room and overhauling the electrical system.

The *HELGOLAND* system (fig. 14) consists of the underwater laboratory with its energy station buoy, the "Igloo," the "Depot," a personnel transfer capsule (PTC), a four-man deck decompression chamber, and one-man rescue chamber. The "Igloo" is an independent underwater station containing compressed air bottles, underwater communications, CO_2 scrubbers, lights, and an acoustic pinger. Divers may take refuge in "Igloo" for rest periods or an emergency. The "Depot" is an underwater station where divers can stand in a bubble of air, remove their mouthpieces, and talk. The characteristics of the *HELGOLAND* are: Depth capability, operational 100 ft, maximum 325 ft (with mooring and life-support modifications); size, 8-ft diameter by 27-ft cylindrical habitat attached to 8-ft diameter by 15-ft cylindrical wet room; living volume 1,500 cu ft; number of divers accommodated 4; towing speed 5 kn; weight of laboratory with wet room 100 t, emergency buoy 14 t (43 ft high); batteries 2,000 amp-hr, 24 V a.c. The habitat is supported by an umbilical cable from an unmanned surface life-support buoy which provides the following: 25 kVA, 380 V at 50 Hz by diesel-electric generator; compressed air supply at 3,000 psi; habitat vent hose; 10-day emergency life support; and two radios and closed-circuit TV communications.

Program Operations

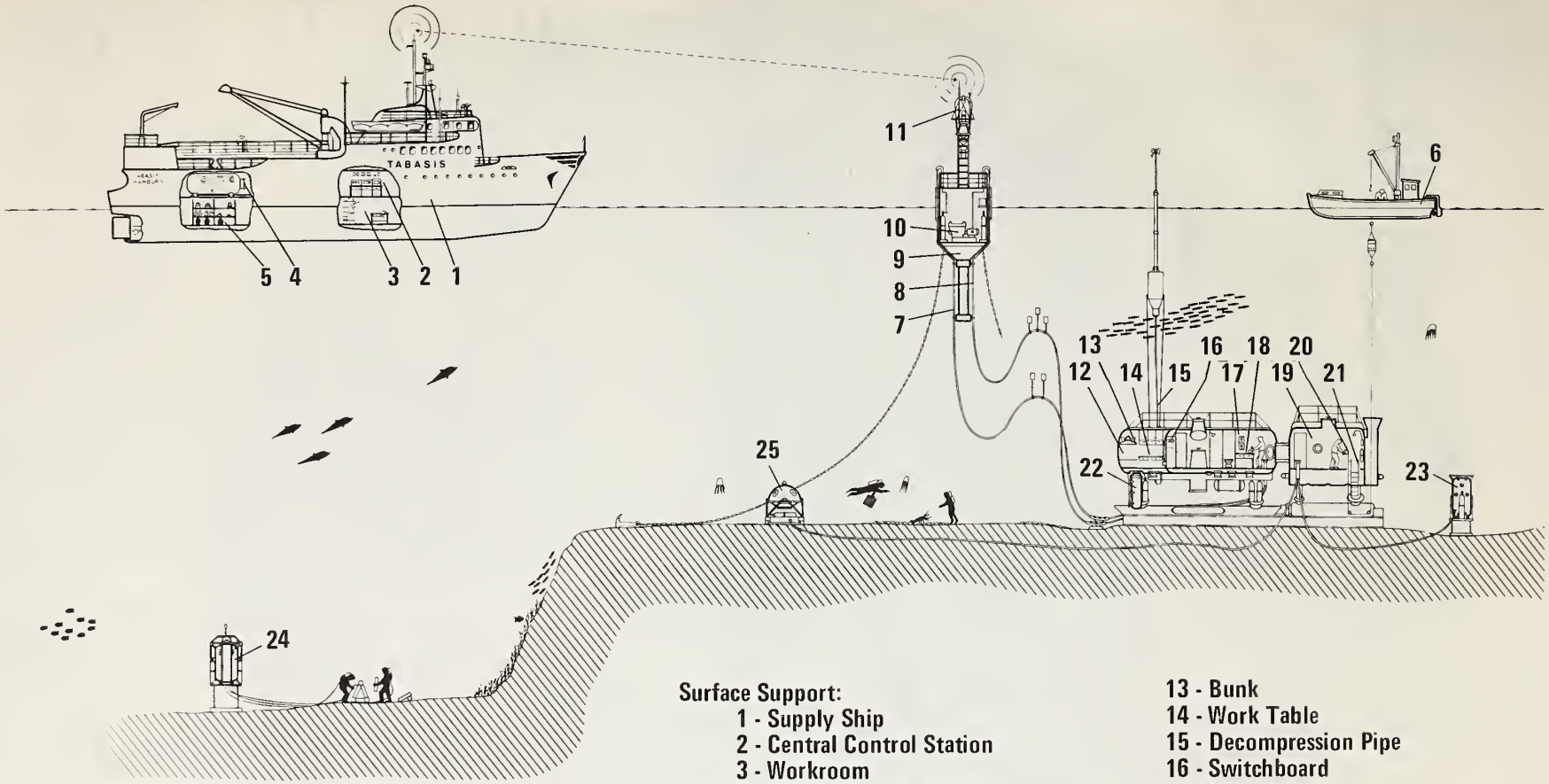
The Polish factory ship *Pomorze* delivered the *HELGOLAND* and the GKSS operations crew to Boston in early September 1975 (fig. 15). Scientists from the Northeast Fisheries Center used the General Oceanographic research submersible *Nekton Beta* for 8 days to directly observe the Project FISSHH site and other historical herring spawning grounds at Jeffreys Ledge. An operations center was established at Pigeon Cove, Rockport. Workshops and support equipment including two four-man decompression chambers were installed at an inn. With the assistance of the Coast Guard, the *HELGOLAND* energy buoy, and other support and scientific gear were deployed by the third week of September. The cover illustration shows an artist's concept of the deployed equipment.

Close liaison was maintained with local fishermen to enable surface teams to check out the progress of herring spawning in nearby areas. The Boston office of NOAA's National Weather Service provided routine weather and sea-state forecasts and special forecasts based on the needs of the project.

The *HELGOLAND* rested on a small rise on the ocean floor at a depth of about 33 m (110 ft). The saturation depth and the water in the hatch was at 31 m (103 ft), with a nominal normoxic mixture of oxygen and nitrogen providing the breathing gas—with the same partial pressure of oxygen as normally breathed from the surface. Because of the limited visibility and cold water, which varied from about 45° to 53°F, a navigation circle of highly visible polypropylene line was laid about the underwater laboratory out to 182 m (600 ft) as shown in figure 16. This figure shows this boundary and the location of various equipment as well as the radial guidelines set at 30 intervals.

The system was occupied, before the first science mission, by a team of three GKSS and one U.S. diver. After a 2-day and 2-night checkout mission and after a 17-hour delay following a 49-hour decompression schedule, the three divers surfaced September 25, 1975. During the return to the surface, one of the German divers suffered a fatal massive air embolism. A NOAA Board of Investigation was immediately appointed. After a full week of intensive and careful analysis, joined by the GKSS Director of the Institute for Technical Installations, which operates the underwater laboratory, it was concluded that the tragedy was in no way connected with the underwater laboratory systems or decompression procedures used. All participants concurred, and Project FISSHH operations were continued.

The original program plan called for 5 dive teams of scientists to log 62 team-days or 248 man-days of saturated "bottom time." About 66 percent of the scheduled bottom time was achieved—41 team-days and 164 man-days. Teams IV and V were canceled owing to



Surface Support:
- 1 - Supply Ship
- 2 - Central Control Station
- 3 - Workroom
- 4 - Decompression Chamber
- 5 - Diver Equipment Storage
- 6 - Supply Boat

Energy Station:
- 7 - Breathing Gas Supply
- 8 - Electrical Supply Cable
- 9 - Fuel Tank
- 10 - Diesel Generator
- 11 - Antenna Installation

Underwater Laboratory:
- 12 - Decompression Chamber
- 13 - Bunk
- 14 - Work Table
- 15 - Decompression Pipe
- 16 - Switchboard
- 17 - Main Room
- 18 - Work Place
- 19 - Wet Room
- 20 - Supply Lift (Elevator)
- 21 - In-and-out Hatch and Ladder

Diving and Rescue Chambers:
- 22 - One-man Rescue Chamber
- 23 - Two-man Diving and Rescue Chamber
- 24 - Three-man Diving Chamber
- 25 - Emergency Shelter ("Igloo")

Figure 14.—*HELGOLAND* dive system.

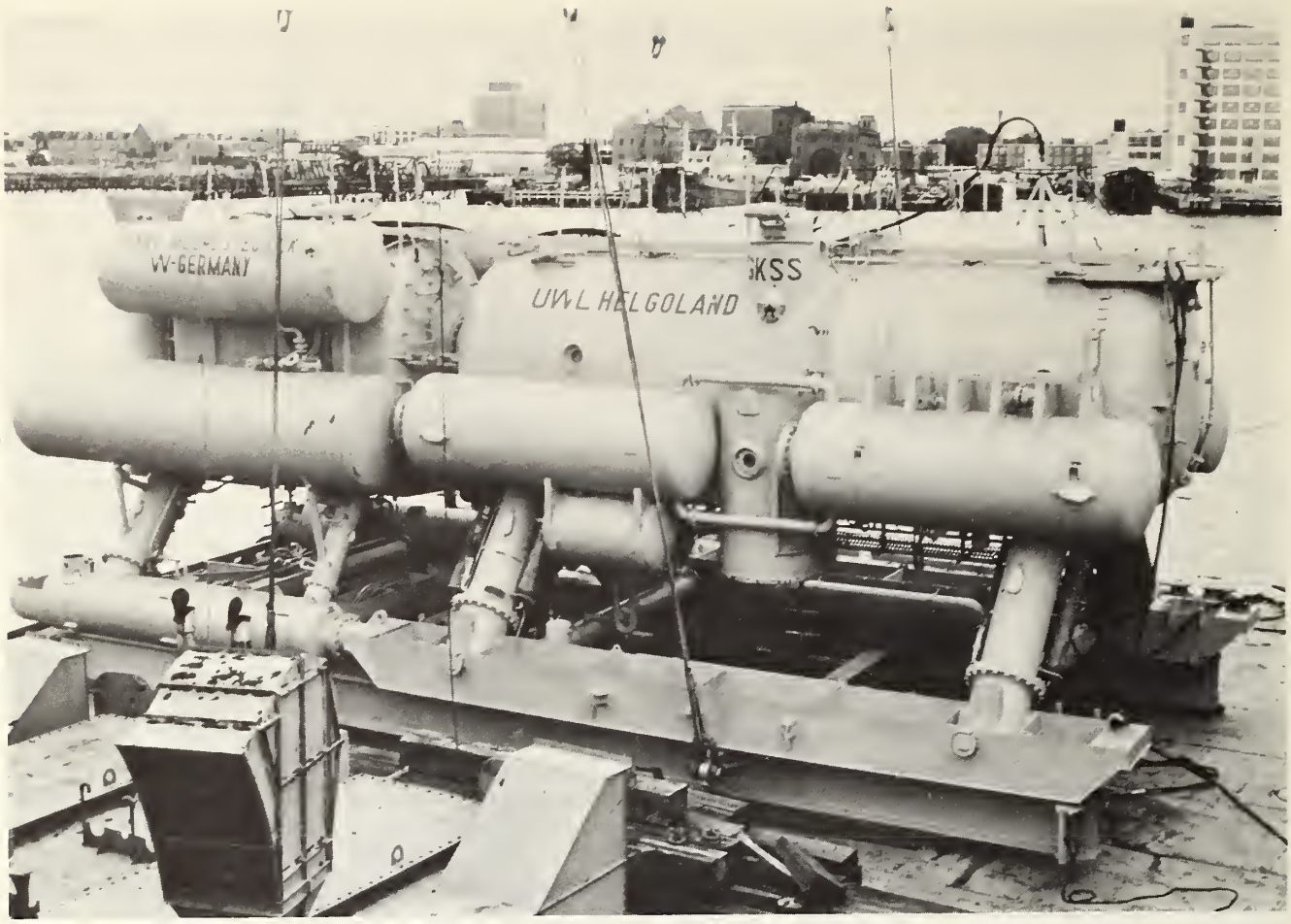


Figure 15.—West German underwater laboratory *HELGOLAND.*

delayed starts of Teams I, II, and III. Each team consisted of three scientists and one GKSS diver technician familiar with the underwater laboratory system.

The first team had just begun deploying scientific gear at the site when the rapid approach of Hurricane Faye on a direct line to the site required an early ending of the team's efforts. With a 49-hour decompression schedule, and after only 2 days on the bottom, the team was brought to the surface by the personnel transfer capsule. It was brought to the surface and moved to shore in a heavy sea state. On shore it was locked to the four-man German DRAEGER decompression chamber at the inn and the decompression was completed without incident.

The second team reentered the *HELGOLAND* on October 4. Although many herring that were ready to spawn were collected near the laboratory, the spawning process was not observed at the site. A complete biological night and day diving survey was made. Surface-based scientists, with the assistance of local fishermen, found herring spawning about a mile west of the underwater laboratory site, beyond the excursion limit of the saturated science divers. They also found herring spawning about 8 to 10 miles to the northwest. After about 2 weeks of saturation, the second team began its 49-hour decompression. The return to the surface was delayed 1 day because of Hurricane Gladys, but by October 20 the team was back at the headquarters.

The third team entered the laboratory on November 4, 1975, made fish-trapping studies, and assisted in placing the hydroacoustic test gear. Individual fish were anesthetized and mounted into hydroacoustical transparent bridles for isonification under various positions of pitch and roll while at fixed distances and positions from the transducer and hydroplane arrays.

A technological success was achieved when, for the first time, divers at the hydroacoustic array under the water were able to communicate directly with the recording vessel. Isonification of fish targets was not possible because of previous time delays in the program caused by the two storms, and time restraints imposed by a termination date. The third team completed decompression and returned to the surface on November 21, 1975.

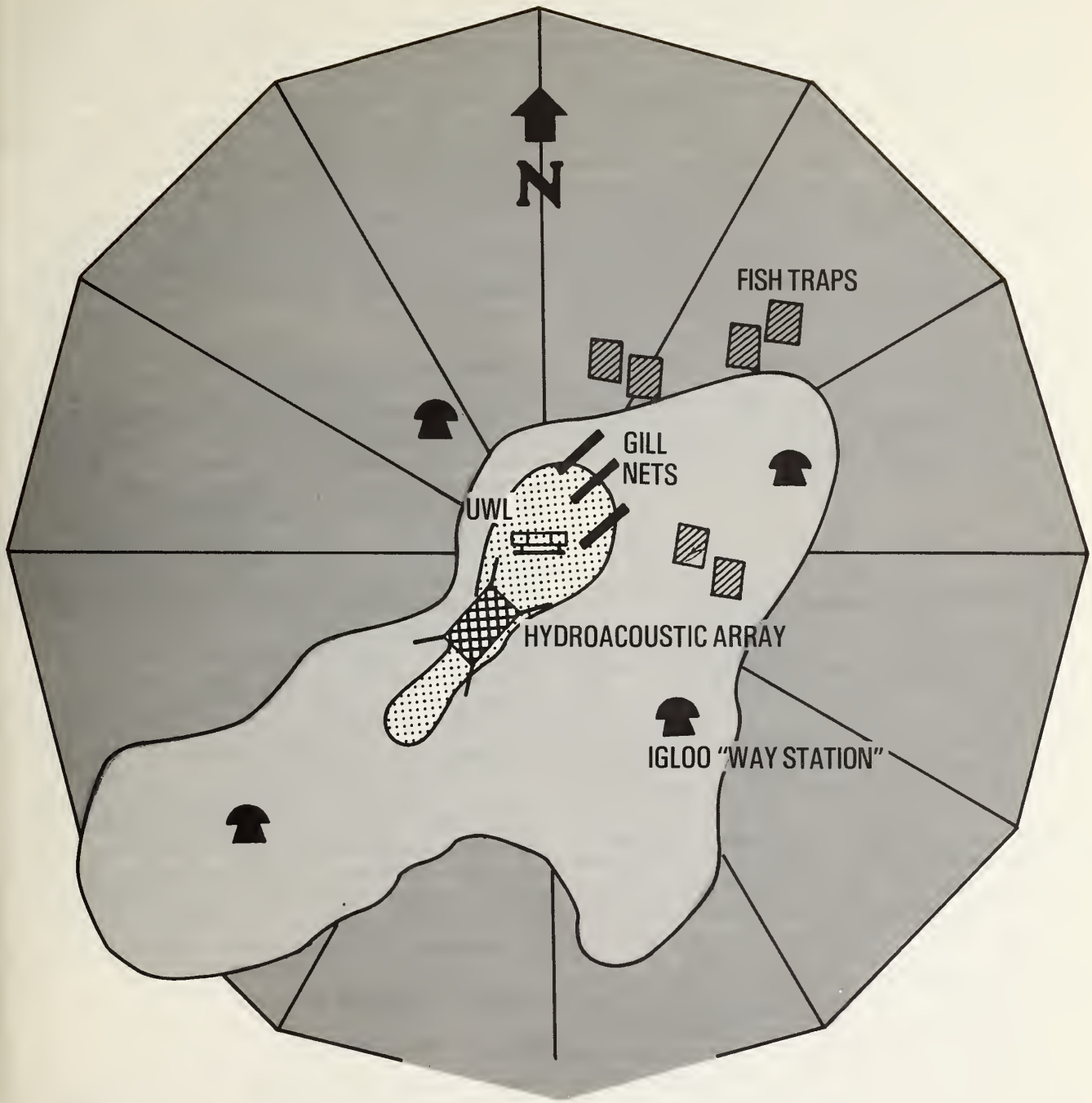


Figure 16.—Location plan for *HELGOLAND* station.

Operationally, Project FISSHH completed the first northern latitude, cold-water, extended-duration, deep saturation diving science program. It was the first program conducted so far from shore and at so great a depth, 33 m (110 ft). The deepest depth at which the *HELGOLAND* had been used before was 21 m (70 ft) in the Baltic Sea. The divers operated out of the underwater laboratory over an excursion distance of 182 m (600 ft), and to depths of 45 m (150 ft). The project provided an important learning experience.

Some major objectives of the science program were not accomplished, primarily because of delays caused by weather, and because in 1975 herring did not spawn on the historic spawning ground. Saturated scientists had expected to average 3 hours per day (excluding decompression time) in the water. They found that 1 hour and 20 minutes, on the average, was all that could realistically be achieved. A total of 215 hours of science-oriented water time was accomplished by the saturation dive teams. An additional 88 hours of science-oriented bottom time was logged over a 3-month period by surface divers. The total bottom time for the science program was 213 hours.

Support vessels and crews were able to operate at the dive site about 70 percent of the time. The ratio of support personnel (shore based and vessel based) to saturated divers on the bottom was 6 to 1, including vessel crews.

Scientific Results

Ecology of Herring Spawning Grounds

A detailed definition of the hydrography, geology, algology, and endemic fauna of the historic spawning grounds was accomplished. Current meters and recording thermographs placed 4 m off the bottom and 10 m below the surface recorded current velocity and direction and water temperature every 15 min during the study period. Smith-McIntyre grab samples (90) and diver collections (15) permitted a detailed analysis of the sedimentology of the historic spawning grounds and the adjacent areas. A complete definition of the attached algae (to which the herring eggs attach) as a function of substrate type and depth was accomplished. The saturation divers took over 2,000 color photographs of the fish fauna and invertebrates that live within the three-dimensional zone of the ocean floor. Collections of all fauna were made with density estimates on certain species. Photographs and collections were made during all periods of the day. Direct observations and sampling of the egg bed were not possible because the herring spawned one-half mile from the *HELGOLAND*, just outside the excursion range of the saturated divers.

Hydroacoustic Experiments

Original hydroacoustic equipment was constructed and deployed to the ocean floor. Fish corrals were stocked with cod and pollock for isonification experiments, which were hampered by time restraints. Diver communication was successful from the undersea hydroacoustic array to the recording vessel.

Fish Behavior and Trapping

Many hours of daytime-nighttime observations on fish (herring, cod, redfish, pollock, flounder, sculpin, sea raven, bluefin tuna, etc.) behavior during calm and rough weather were made. The first in-situ observations of schools of adult herring on the spawning grounds and the predation of other fish upon them were accomplished. The reactions of fish schools to unnatural sounds from the surface,i.e., presence of a ship and the noises associated with it, were observed.

The saturation teams tested several techniques of fish trapping and corralling. Underwater gill nets of a variable mesh were very effective for capturing cod and pollock. Underwater corrals were effective in holding the captured specimens.

Scientific Diving Advancement

Project FISSHH provided significant learning experiences for all diving personnel. FISSHH provided the first scientific saturation diving program at the depths of 33 m to 45 m (110 to 150 ft) and at a distance of 16 km (10 mi) from shore in northern latitudes.

Dive procedures under saturation conditions were standardized early in the program. Navigation lines radiated from the *HELGOLAND* like spokes of a wheel to a distance of 182 m (600 ft). All excursion diving was conducted along these lines. There were no dive equipment failures, and the underwater wireless or sonar communications worked well. Diver propulsion units proved effective. Unisuits were worn by all saturation divers, permitting divers up to 1.5 to 2.0 hours in the water per dive before getting chilled.

Hurricanes, severe storms, habitat movement in very rough sea conditions and the ever-present sea-air interface problems re support activities in bad weather were the major operational problems encountered. Diver scientists were unable to reach the herring egg bed, because of the "fixed position" characteristics of *HELGOLAND* and the 182 m (600 ft) excursion limit imposed on the saturation teams.

US/FRG LUBECK II

Habitat: HELGOLAND

Purpose of program: Develop and use in-situ instrumentation and techniques for the acquisition of chemical, physical, and biological programs, including biochemical and chemical oxygen demands of sewage as a function of time, bed thickness, and suspension in the water column; compare the merits of several welding processes under actual diving conditions; and evaluate, improve, and extend the capability of an engineering model of a wrist-worn decompression computer.

Location: Lubecker Bucht, Baltic Sea, Federal Republic of Germany (FRG)

Dates: June 24 to July 31, 1976

Duration: 112 man-days of bottom saturation time (28 team-days)

Depth: 16 m

Sponsor: NOAA/MUS&T

Background

As part of previous U.S. (NOAA/MUS&T) international underwater activities and in cooperation with foreign countries, a joint US/FRG mission was organized in early 1976 for early summer 1976. This mission was the second joint US/FRG program in the Lubeck area. The field organization, personnel, and international organizations were as follows:

Field Organization

U.S. (NOAA) Managing Personnel:

Project Manager—J.M. Wells, MUS&T

Deputy Project Manager—T. Ruszala, NMFS/NEFC

U.S. Participating Institutions:

Manned Undersea Science and Technology (NOAA/MUS&T)
Rockville, Md.

National Marine Fisheries Service (NOAA/NMFS)
Highlands, N.J., and
Woods Hole, Mass.

Virginia Institute of Marine Science (VIMS)
Gloucester Point, Va.

Virginia Polytechnic Institute and State University (VPI&SU)
Blacksburg, Va.

University of Georgia, Institute of Ecology (U.GA)
Athens, Ga.

Massachusetts Institute of Technology (MIT)
Boston, Mass.

Naval Undersea Center, U.S. Navy (NUC)
Kailua, Hawaii

Naval Sea Systems Command (COMNAVSEASYSCOM)
Washington, D.C.

U.S. Project Personnel

Science Program—Mission A

VIMS	M. Lynch	Principal Investigator
	M. Castagna	Science Coordinator
	K. Webb	Investigator
	W. Hargis	Observer
	R. Middleton	Investigator
NOAA	W. Phoel	Investigator
U. GA	W. Campbell	Investigator
	G. King	Investigator

Technology Program—Mission B:

NUC	R. Seiple	Investigator
	K. Jennings	Principal Investigator
VPI & SU	R. Skutt	Investigator
	W. Rahim	Investigator

Technology Program—Mission C:

MIT	K. Masubuchi	Principal Investigator
	M. Greer	Investigator
	H. Ozarki	Investigator
	C.L. Tsai	Investigator
	J. Chiba	Investigator
COMNAVSEASYSCOM	J. Bladh	Adviser
	BMC(MDV) H. Harper	Adviser

International Organizations and Personnel

Admiralty Experimental Diving Unit Portsmouth, England		Observer
Gesellschaft fur Kernenergieverwertung in Schiffbau und Schiffahrt mbH Geesthacht, Federal Republic of Germany	H. Schafstal	Director

Scientific and Technical Programs

Mission A. Science Program

Purpose of program: In-situ benthic metabolic measurements related to sewage sludge transport.

Principal investigators: J. Morgan Wells, W. Phoel, and W. Campbell

Background and Objectives. Previous joint MUS&T and EPA studies in the Bahamas were made to determine the fate and effects of digested domestic sewage sludge in the sea. Such processes are sensitive to environmental variables, especially temperature. The environmental conditions at the Lubeck Project site in the Baltic Sea are more typical of U.S. areas where sewage sludge is now being dumped, than conditions at the Bahamas site. Thus, the Lubeck offshore area was chosen for experiments on sewage sludge which include:

1. Biochemical oxygen demand,
2. Chemical oxygen demand,
3. Nutrient (nitrogen and phosphorus) exchange with the water column, and
4. Effects, on the above, of (a) low temperatures (6° -10°C), (b) resuspension, (c) time of exposure to seawater, (d) bed thickness, and (e) perturbation by marine animals.

This type of information is essential for understanding the assimilative capacity of the ocean for the high levels of organic material and nutrients found in sewage sludge that are now a problem of dumping off U.S. coasts. Data are required to estimate the quantities of sludge that can be dumped and the dilution that must be used to prevent significant environmental damage.

Experimental Techniques—Purposes. Develop and use in-situ instrumentation and techniques to:

1. Model substrate—water-column interaction in terms of turnover rates and sources/sinks of carbon, nitrogen, and phosphorus.
2. Determine the role of sediment/water and water/water interfaces in the energy and nutrient budgets.
3. Make simultaneous studies of the metabolism of oxygen, nitrate, nitrite, ammonia, and phosphorus.
4. Determine the chemical oxygen demand of the water column and sediments.
5. Determine the carbon and nutrient metabolic responses to photosynthesis inhibitors, and establish dose-response curves for altered levels of oxygen and nutrients.
6. Make quantitative studies of methanogenesis in sediments, nitrogen fixation in the water column and sediments, and denitrification in sediments.
7. Determine microbial quantity and energy charge ratios of the water column, sediment, and physical boundary layers.

Method and Results. In-situ instrumentation for these experiments included: Diver-held transmissometer, diver-held oxygen/temperature meter, diver-held quantum meter (light), diver-held salinometer, oxygen/temperature surface-to-bottom profiler, and habitat-based microgas chromatograph.

Chemical techniques were used in the underwater laboratory and surface laboratory to determine nitrate, nitrite, ammonia, phosphate, oxygen, ADP and AIP, and methane.

The data are being analyzed, and a comprehensive report on the results is being prepared. Preliminary "quick-scan" results indicate:

1. Phosphorus metabolism was drastically affected by even small changes in temperature.
2. Photokinetic-chemical reactions with the primary and secondary products of sewage were noticeable to depths of 5 m, but below those depths photo or "light" reactions quickly became a negligible factor in the chemical balance.
3. Methane exudation (at 20- to 30-in depths) of sea bottom sewage sludge and mud was negligible.
4. Water O_2 content (at various O_2 transport rates) was most effective in the breakdown of sludge and sewage.

Mission B. Technology Program

Purpose of program: To study and evaluate diver safety problems and technology. Experiment 1—Diver Communications. Experiment 2—Decometer Test and Evaluation.

Principal investigator: H. Richard Skutt, Department of Electrical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Va. 24061.

Experiment 1: Two ultrasonic telemetry systems were tested and evaluated as part of the Lubeck II operation using the *HELGOLAND* underwater laboratory in Travemunde, Germany.

Digital Diver Communications System (DDCS). The purpose of this system is to allow the diver to transmit up to 16 precoded messages to a receiving station (ship or underwater laboratory) by positioning four waterproof switches. Each set of switch positions causes a unique digital message to be sent to the receiving station using 50 kHz ultrasonic energy bursts.

Tests were made during surface dives near the *HELGOLAND* underwater laboratory. Results are as follows:

1. The basic approach is feasible in an ocean environment.
2. The system worked for short-range tests (up to about 200 ft, depending on background noise).
3. The system was found to be susceptible to background noise sources of a continuous nature (in contrast to random "spike" noise). This is a flaw in the electronic design and resulted in incorrect messages except for short ranges as noted.

This problem can be corrected by adding more filter mechanism components.

4. The Plexiglas housing for the transmitter worked well, with no leaks.
5. The system is very useful when voice communication is poor or impossible from diver to ship, but adequate from ship to diver. For example, the diver can hear questions being asked and can respond by "yes" or "no".

Diver Physiology System (DPS). This system is designed to transmit four channels of data (heart rate, body temperature, skin temperature, and respiration rate) to a receiver on the surface or in an underwater habitat. Each channel uses a different frequency (48.5, 49.5, 50.5, and 51.5 kHz) that is crystal controlled. A single transducer (centered at 50 kHz) is used for all four channels. The receiver has similar crystal-controlled circuits to selectively restore the four channels of data. Test results follow:

1. The basic method of data transmission is very good. Reliable data transmission with good range (up to a few 100 m) can be obtained.
2. The prototype housing for the transmitter system was damaged during the first test, and saltwater leaked into the electronic circuits. This caused several component failures. Repairs were made on the system, as much as possible, but it could not be restored to full operation. The effort was "almost" successful, but the final blow occurred on the last day, when the batteries were discharged by the failure of additional components when a saltwater leak occurred.
3. The use of high-resistance thermistors for temperature measurement caused current leakage (caused by saltwater "contamination" of waterproof connections).
4. The technique of placing waterproof ECG electrodes on a diver for several days at a time was not a success. In the humid environment of the habitat, the electrodes irritated the skin. No known method of attaching electrodes is satisfactory in such an environment over a period of several days.
5. The device noise in the receiver system limited range and can be avoided by additional filtering.
6. Results show that the use of matched crystals at the transmitter and receiver is a very good choice for greatest range and power consumption.
7. Difficulties were encountered in recharging batteries for the transmitter. These were due mainly to the accessibility of power sources in the habitat.
8. The method used to obtain respiration rate (impedance variation) is subject to artifacts produced by body motion.

Conclusions

1. The electronics part of the two systems functioned properly and would give valid data in a "safe" environment.
2. Mechanical considerations (housing, waterproof connectors, switches, etc.) must be much more rugged than in the present system.
3. Heart rate cannot be obtained routinely in the ocean using surface electrodes. Another reliable method must be found.
4. Any system for routine safety purposes for ocean divers must be extremely rugged, reliable, and easy to use.
5. The basic method of data transmission is quite good.
6. Low resistance levels should be used for all transducers, because the unavoidable problem of saltwater and humid air causes leakage currents across terminals of connector pins.
7. Additional filtering should be added at the receiver to achieve the full potential of the matched crystals being used for each channel frequency.
8. The method used to obtain respiration rate is not good enough. These data may best be obtained from voice transmission.
9. Divers are reluctant to use a rectal probe in routine situations.
10. Skin temperature data are of little use.

Experiment 2: Three decometers were brought to Lubeck; two packaged for divers' use and one for use in the underwater laboratory *HELGOLAND*. All three units were programed for air dives (79 percent nitrogen). The tests, done in the Baltic, were valuable in providing observation of the decometer by divers outside NUC. The diver units were worn by surface and saturated divers with the following observations: 1) The wrist strap should be redesigned—units slip down arm; 2) a light filter or a shade should be put over the display to prevent washout by ambient light; 3) the display should be labeled (depth and safe ascent depth), and the implied "0" on safe ascent depth etched in.

On the positive side, the units did function as programed and the battery life of the units was in excess of 12 hours (further tests will be made to determine exact time).

The decometer unit, which used power from the underwater laboratory's battery supply, loses the contents of its memory when the batteries are switched. A parallel battery should be on line to prevent this, and the display should be labeled depth and safe ascent depth to avoid confusion. Otherwise this unit functioned as programed.

The changes suggested will be incorporated into the next units.

Mission C. Technology Program

Purpose of program: In-situ underwater welding experiments were performed with various fluxes.

Date: June 14 to July 20, 1976.

Investigators: Koichi Masubuchi, Hironori Ozaki, Chon-Liang Tsai, Matthew N. Greer, and Junichi Chiba, Massachusetts Institute of Technology, Boston, Mass.; J. Bladh, USN Adviser.

Introduction. The objective of this experiment was to collect scientific data on underwater welding and to evaluate two welding processes under actual diving conditions.

The processes evaluated were 1) the shielded metal arc welding process, and 2) the flux-shielded metal arc welding process that is widely used for underwater repair work. The flux-shielded metal arc welding process, developed at MIT, reduces water quenching around the arc zone by direct flux shielding.

This report reviews the experiment proposal issued on May 19, 1976, and describes the progress of the experiment and a schedule for the remaining work.

Brief review of the project. The study consisted of two phases:

Phase 1: The study of an operational system that included cost analysis, electrical safety, and diver's stability and fatigue rate.

Phase 2: The evaluation of two underwater welding processes with respect to 1) arc stability and metal transfer, 2) bubble formation, 3) heat flow, 4) metallurgy, and 5) mechanical properties.

Also included were studies of:

1. Type of flux coating of electrode (rutile, low hydrogen, and special coating for underwater application).
2. Type of waterproofing (duralic and epoxy).
3. Type of joint (butt and tee).
4. Welding positions (downhand and vertical).
5. Optimum welding current (D.C.R.P.) and voltage (drooping characteristic) with respect to each individual weld.
6. Base materials (mild steel and high-strength steel—thickness: 6 mm and 13 mm).

Several ways of examining welds were also suggested in the proposal, including:

1. Examination of metallurgical structures of weld metal, heat-affected zone, and base metal.
2. Examination of weld defects such as porosity, undercut, slag inclusion, lack of fusion, and lack of penetration.
3. Determination of mechanical properties, which included tensile strength, ductility, notch toughness, and microhardness.
4. Examination of other qualities such as chemical composition and segregation of weld metal, arc stability and metal transfer, composition of gas bubble and its generation rate, and heat flow in the weldment.

The use of a chart recorder, underwater photographing, and underwater TV monitoring was also proposed. Multipass butt joints were used for detailed mechanical examination. X-ray inspection was used for all welded samples.

Description of the experiment. The welding experiment was completed with the help of GKSS and NOAA on July 17, 1976. A brief description of the experimental conditions and the status of the work done is itemized as follows:

Working conditions:
- —Depth: 12.5 m (diving time; 80 min/day)
- —Temperature: 6° to 7°C on the average
- —Visibility: good in general
- —Underwater current: low in general

Welding conditions:
- —Power supply: drooping characteristic
- —Polarity: D.C.R.P.
- —Welding speed: 20 cm/min on the average

Material:
- —Base plate: Mild steel and high-strength steel (HT 52)
- —Thickness: 6 mm and 15 mm (instead of 13 mm)
- —Electrode: A, regular E7014 (3/16 in diameter by 14 in. long); B, underwater welding electrode (MIT); C, underwater welding electrode (1/8 in. diameter by 14 in. long) E7018 and austenitic electrode (E310-16)
- —Waterproof: Duralic and epoxy
- —Normally, four divers were involved in the experiment including a welder/diver, a research diver, an emergency and assistant diver, and an MIT diver.

Tentative experimental results.
1. Samples completed (table 10)
2. Four reels of video tape were obtained
3. About 30 photographs were taken
4. Two gas samples were taken
5. Welding current and arc voltage of every welding session were recorded by the chart recorder
6. All the samples were inspected radiographically and then sent to MIT for further testing
7. A bubble gas analysis was done at GKSS. The results were sent to MIT.
8. An electron microprobe analysis (EPMA) was done at GKSS.

Table 10.—Welding experiment samples completed

Process	Type of electrode	Type of Joint: Butt Single D	Butt Single V	Butt Multi D	Tee Single D	Tee Single V	Bead on plate D	Subtotal	
Shielded Metal Arc	A-duralic	4	3	1	5	3		16	
	A-epoxy	3	1		3	1		8	
	B-duralic	1	1	1	1	1		5	
	B-epoxy	3	1	1	2	1		8	
	C			1			1	2	
	E7018	1			2			3	
	E310-16				1			1	43
	Austenitic						1		
Flux-Shielded Arc	A-epoxy	2						2	
	B-duralic	2						2	
	C						1	1	5
		16	6	4	14	6	2	48	48

NOTE: A, B, C; see V-(3); D, downhand position; V, vertical position. The total number of welded samples is 48. The welding current was basically changed in three different values.

United States—Japan Program

The Third Meeting of the UJNR Panel on Diving Physiology and Technology took place from July 18-26, 1975, in Tokyo, Okinawa, and Kokura. Much useful information was exchanged.

The third joint project between scientists of the University of Hawaii and the Japan Marine Science and Technology Center (JAMSTEC) was carried out successfully at Yokosuka. The project involved an extensive dry chamber dive. The Diving Physiology and Technology Panel will continue to expand this cooperative program.

In addition, the UJNR Panel hopes to initiate a program on mutually agreed-upon standard methodology for measuring diver performance, diving equipment standards, and methods of standardized data collection.

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